Essays in Macroeconomics

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Introduction

The recent financial crisis, and the "Great Recession" that accompanied it, has revived interest in activist fiscal policy as a way to stabilization the business cycle and has put back the evaluation of fiscal policy at the core of the economic debate. This is the main question of this dissertation, which addresses three distinct, although tightly related, issues on the fiscal policy in context of the business cycle: *(i)* the empirical evaluation of the potency of fiscal policy by means of the comparison of the fiscal multipliers following a shock affecting one of the main components of government spending —government consumption, investment, and labor compensation—in a unified framework , *(ii)* the evaluation of the potency and efficiency of individual fiscal instruments, typically used by governments for public debt financing, in stabilizing the business cycle in a medium scale Dynamic Stochastic General Equilibrium (DSGE) model, and *(iii)* the quantitative evaluation of employment (and output) losses generated by fiscal consolidation policies.

Governments in most industrialized countries have responded to the Great Recession by designing rather aggressive stimulus packages, which combine increases in government expenditures —both consumption and investment expenditures— and tax cuts. Chapter 1 of the dissertation addresses the question of the effectiveness of such policy measures by evaluating the size of the multipliers associated with such policies. It provides a comparison of dynamics, both in terms of impulse responses and multipliers, of the main macroeconomic aggregates following a shock affecting one of the main components of government spending –*i.e.* government consumption, government investment or labor compensation. This chapter, in particular, attempts to fill the existing gap in literature by studying the potential differences existing between unproductive and productive expenditures and transfers. This is achieved by providing a unified framework relying on a Vector AutoRegressive (VAR) model. These models allow to recover the dynamics of various variables in the aftermath of structural shocks that hit the system, the so called impulse–propagation framework. The question is then that of the identification of the structural shocks. In this chapter, I rely on the identification scheme proposed by Mountford and Uhlig (2009) whereby sign restrictions are used to place restrictions on the response of the main macroeconomic aggregates to identify the shocks of interest. These restrictions are then used to recover, in the following order, *(i)* a business cycle shock, *(ii)* a monetary policy shock, *(iii)* a government spending shock and *(iv)* a government revenue shock, which are all mutually orthogonal. This approach ensures that the so recovered government shock does not reflect the endogenous response of fiscal authorities to alternative macroeconomic shocks. The main results indicate that government consumption shocks —either affecting total expenditures or defense expenditures only— lead to a mild positive response of both consumption and output with the associated multipliers below unity for both output and consumption. The shock crowds out the private investment and this effect is stronger when the shock affects productive expenditures –*i.e.* government investment. Furthermore the results show, in line with the theory, that a shock to government investment generates through the accumulation of public capital, a positive wealth effect that makes the multipliers larger in the longer run. These results remain unaffected when we consider either total government or defense expenditures. When the shock affects labor compensation then multipliers are larger (about 1.5) due to the absence of crowding out effect on the good market. They also reveal that the size of the associated multipliers is sensitive to the sample. In particular, the inclusion of the most recent period, where financial frictions were more prominent, tends to increase quite dramatically the size of the multipliers. This is reminiscent of recent theoretical papers, such as Fernández-Villaverde (2010) or Canzoneri, Collard, Dellas, and Diba (Forthcoming), which suggest that the presence of stronger financial frictions has a non-linear effect on the transmission of fiscal shocks and amplify their effect on aggregate variables. The chapter therefore offers an investigation of the potential non-linear effects associated with the financial conditions through the estimation of a non-linear VAR in which an indicator of financial conditions is interacted with macroeconomic variables. The presence of the non-linearity complicates the computation of impulse responses, and I rely on the Generalized Impulse Function analysis à la Koop, Pesaran, and Potter (1996) to properly capture all potential effects of these non-linearities. The results are, again, in line with the theory in that the size of the multiplier is larger as financial conditions deteriorate. They indicate in particular that multipliers are larger when the financial conditions are tight and that a deterioration of financial conditions leads to an increase in the multiplier associated with a government consumption (resp. investment) shock of about 25% (resp. 25%). Using the same methodology, we also show that when the economy hits the zero lower bound, the multiplier increases further by about 40% in the case of a government consumption shock and 25% in the case of a public investment shock. We conclude this interaction between financial frictions and monetary policy accounts for the increase in the multiplier during the last financial crisis.

Governments' responses to the Great Recession have resulted in significant public debt buildups that, in turn, have raised concerns about the financing of the various fiscal stimulus packages adopted by most industrialized countries. Between 2004 and 2012 the sovereign debt to GDP has increased around 35 percentage points for France, Greece, and United States; and for countries like Portugal and United Kingdom the corresponding increase reached 60 percentage points. There thus seems to exist a trade-off between using fiscal instruments as a way to stabilize the business cycle and fiscal discipline, as manifested by the posted willingness of governments to keep public debt under control. This trade-off ought to limit the effectiveness of governments in stabilizing the business cycle. The objective of Chapter 2 is to investigate this issue by asking, in particular, the question of implementation of fiscal rules in a full-fledged estimated DSGE model.

This chapter extends a medium scale DSGE model à la Smets and Wouters (2007) to the presence of an active fiscal policy. The model therefore features nominal frictions in the form of sticky prices and sticky wages, an active monetary policy in the form of a Taylor rule and various real rigidities (habit persistence, investment adjustment costs,...). On the fiscal policy front, the model features distortionary taxes (consumption, labor and capital) as well as an explicit fiscal rule. Contrary to the existing literature on fiscal rule which specifies a rule for each tax/spending instrument, fiscal policy is modeled as a single rule where the total tax revenues responds both to a measure of the output gap and to the level of public debt. Such a design of the rule therefore does not take a stand *a priori* on which of the two sides of the aforementioned trade-off matters the most –stabilization or fiscal discipline– instead it lets the data speak. Given exogenous government spendings, this rule can, alternatively, be given a “deficit rule” interpretation. Hence, the government has a primary deficit objective which aims at achieving output stabilization while maintaining public debt under control. It then adjusts the tax system to finance it. Which of the tax should be adjusted is *a priori* indeterminate. Only one instrument, at the time, is therefore used to achieve this increase in tax revenues, holding all other distortionary tax rates (and the lump sum tax) constant. One contribution of this chapter is to propose a modeling that allows for a separation between the stabilization policy from its financing, and as such provides us with a structured framework to understand these two aspects of fiscal policy. The question of the implementation is important as different tax instruments may lead to different outcomes both in terms of potency and efficiency. Furthermore, the model takes into account the interaction between fiscal and monetary policies, which ought to have significant implications both for financing of public debt and output stability. The model is estimated on U.S. data using a Bayesian maximum likelihood method in the frequency domain. This approach allows to focus on business cycle frequencies, which are of interest for stabilization purposes.

One result of this chapter is that once the objective is set, its exact implementation does not matter from a positive point of view. Indeed, the results indicate that the choice of the tax instrument used to balance the government budget constraint quantitatively affects the propagation of shocks. The most stabilizing tax, in terms of unconditional output volatility, is the lump sum tax as it does not distort any of the agents' decisions. However, since the lump sum tax is essentially absent from most tax systems governments have to rely on distortionary taxation. Ignoring the lump sum tax, the labor tax is the most stabilizing tax, in terms of output volatility, followed by the consumption tax and the capital tax. However the differences are quantitatively small, suggesting that the implementation does not matter much for unconditional volatility. Thus, as soon as the government uses a deficit rule, the exact details of its financing have very little quantitative consequences for the positive properties of the economy. This stands in contrast to models that specify a rule for each tax rate in the system (for example Leeper, Plante, and Traum (2010)) where altering one particular tax rate (and hence one of the tax rules) can have sizable consequences for the business cycle properties of the model –both in terms of volatility or co-movements. Furthermore, the results show that the policymaker is not in a position to affect the contribution of each shock to the business cycle by simply varying the tax instrument she uses while using a simple deficit (or total tax revenue) rule.

The preceding results however do not totally rule out the potential importance of the implementation. In fact, this chapter shows that the labor tax model allows to achieve output stabilization without much volatility in tax revenues and public debt. Expressed differently, the positive properties of the tax system are strongly affected by the implementation and it ought to have strong implications for a normative analysis. Such an analysis is however beyond the scope of this chapter, but two points are noteworthy. First, the presence of a time varying tax adds an additional time varying distortion in the model beyond the price and wage markups, which can add to the welfare cost of fluctuations for the agents. Second, when the central bank takes fiscal policy as given, the presence of a time varying tax rate affects the form of optimal monetary policy by re-introducing the inflation output stabilization trade-off.

Chapter 3 then investigates the implications of fiscal consolidation policies for unemployment. High levels of public debt that accumulated following the Great

Recession have significant economic consequences and in particular in terms of growth (see Reinhart and Rogoff (2010)). Thus, in an attempt to reduce public debt governments in most advanced economies have been making efforts to design and implement most appropriate fiscal consolidation plans. A sizable literature that studies that effect of fiscal consolidation has shown that the effects of fiscal consolidation episodes on output vary significantly with the fiscal instrument used to achieve the fiscal consolidation, the timing, the speed and the size of the consolidation. This then hints to the importance of "right" design of a fiscal consolidation plan.

Although the literature has extensively analyzed the output losses associated with the consolidation episodes, the effect on the (un-)employment remain largely unconsidered. This is however of interest because *(i)* most of the countries that undergo a fiscal consolidation are countries that experience high and persistent unemployment rate, and *(ii)* countries in which unemployment is still at a low level may also need to evaluate the potential output loss for monetary policy considerations. It is therefore of interest to evaluate *(i)* the potential employment loss (rise in unemployment) associated with debt consolidation episodes and *(ii)* the persistence of this loss. This chapter therefore offers a theoretical framework —a dynamic general equilibrium model— that permits such an evaluation. In particular, it extends the standard neoclassical growth model to *(i)* the presence of public debt and *(ii)* the search and matching frictions in the labor market. The existence of frictions on the labor market, in particular, permits to study employment dynamics and to derive a measure of employment loss associated with fiscal consolidation episodes.

In the model, sovereign debt reduction is achieved either by tax hikes or government expenditures cuts, which plunges the economy in a persistent recession and therefore generates output and employment losses. In the main experiment —a targeted 25% debt reduction— unemployment increases by about 50%, starting from 5.5% and reaching 7.3% after 3.35 years. These employment losses are persistent and last on average 12 years. Furthermore, at the trough of the recession (4.5 years following the beginning of the adjustment), output is 1.5% below its initial steady state. During the times of recession, these losses are especially severe due to the competing goals imposed on the labor tax adjustment by *(i)* fiscal consolidation and *(ii)* output stabilization.

Further results suggest that sizable and faster debt adjustments are associated with bigger employment and output losses. One the one hand, the quicker debt reduction involves bigger initial adjustment which magnifies the employment loss in the short–run. However, economy recovers quicker compared to a gradualist approach. On the other hand, a slower adjustment allows for smoother debt adjustment that limits the initial employment loss, which, however, lasts longer, therefore implying a lower but more persistent effort. These findings point to the existence of an intertemporal trade–off between short–run losses from fiscal consolidation and long–run gains from reduced debt. Furthermore, the results indicate that the exact details of the consolidation plan do matter; government spending cut versus tax hikes, the type of tax instrument used to achieve fiscal adjustment, and the timing of the plan. The chapter also investigates, as an extension, a version of the model featuring nominal frictions and monetary policy. In that particular setting, monetary and fiscal policies interact. For instance, an increase in the interest rate triggered by the central bank raises debt services, which leads the government to adjust the tax (as debt has to be reduced), which impacts on the tax burden faced by the households.

Chapter 1

The Effects of Government Policy Shocks*

1.1 Introduction

The recent financial crisis, and the "*Great Recession*" that accompanied it, has put back the evaluation of fiscal multipliers at the core of the economic debate. Governments in most industrialized countries have responded to the Great Recession by designing stimulus packages, which combine increase in government expenditures and tax cuts[1]. The question of the effectiveness of such policy measures led to a revival of exercises aiming at evaluating the size of fiscal multipliers. However, besides some rare exceptions (see for example Pappa (2009)), most studies focus

*This chapter was co-authored with Fabrice Collard.

[1] As outlined in a "European Economic Recovery Plan" issued on 26 November 2008 in Brussels, the European Union passed a 200 billion euros stimulus plan. In particular, a plan required that each member country develops their own national plans, worth 170 billion to 200 billion euros in total, and an EU-wide plan of 30 billion euros coming from EU funding. For example, the United Kingdom in "Pre–Budget Report 2008" outlined a stimulus plan totaling around 20 billion pounds (and not including loan guarantees). The US Congress passed the "Economic Stimulus Act of 2008" outlining a fiscal stimulus package, including more than $100 billion of personal tax rebates and further measures aimed at stimulating business investment. The United States combined many stimulus measures into the "American Recovery and Reinvestment Act of 2009", a $787 billion bill covering a variety of expenditures from rebates on taxes to business investment.

on unproductive expenditures, therefore ignoring the potential differences existing between this type of expenditures and productive expenditures or transfers. This paper is an attempt to fill this gap using a unified framework, namely a Vector AutoRegressive (VAR) model. Beyond offering a comparison of multipliers across types of expenditures, we investigate whether there was indeed something "*special*" about the last recession episode, or whether the size of multipliers is simply affected by financial conditions.

This paper is related to the vast empirical literature (see for example Fatás and Mihov (2001), Favero (2002)) that, following the seminal paper by Blanchard and Perotti (2002b), attempted to recover the effects of government expenditures shocks on macroeconomic activity and the level of the associated multipliers in VAR models. In these VARs the government expenditure shock is identified by assuming that macroeconomic aggregates respond to this shock with a lag, which therefore amounts to rely on the Cholesky decomposition of the covariance matrix of the residuals of a VAR model. We do not follow this approach and rather use the identification scheme proposed by Mountford and Uhlig (2009) who impose sign restrictions on the impulse responses in identifying, in the following order, *(i)* a business cycle shock, *(ii)* a monetary policy shock, *(iii)* a government spending shock and *(iv)* a government revenue shock, which are all mutually orthogonal. An advantage of this approach is that it permits to ensure that the so recovered government shock does not reflect the endogenous response of fiscal authorities to alternative macroeconomic shocks. We however depart from Mountford and Uhlig (2009) in that we do not restrict our approach to unproductive government consumption expenditures, we also investigate the effects of productive public investment expenditures and government compensation. We also consider total and defense expenditures, the latter being usually thought of as essentially exogenous with regard to the business cycle. In that respect, our paper is close to that of Pappa (2009) who also investigates this issue but mainly focuses on its effects on employment. Our aim instead is mainly to recover the effects of such shocks on aggregate output, consumption and investment and to also compute the associated fiscal multipliers.[2] We also investigate systematically how the inclusion of the financial crisis has potentially affected the size of the multiplier. In particular, we highlight the differences between the various types of spending and how these results are actually sensitive to the sample we use. The VARs are estimated for two time frames: *(i)* the pre-financial crisis period, 1955I-2007IV, and *(ii)* for the period including the financial crisis, 1955I-2012IV.

Our paper also relates to the recent literature that, following Auerbach and Gorodnichenko (2012), attempts to investigate to what extent fiscal multipliers are state dependent—*e.g* whether their size and persistence vary over the business cycle. For instance, Auerbach and Gorodnichenko (2012) report that multipliers are typically well above unity during recessions—*e.g.* of the order of 2.5, and fall below one during booms.[3] We however depart from their approach in two significant ways. First, we do not attempt to assess the potential state dependence of the multiplier with respect to the business cycle itself, but rather to financial conditions. In that respect this paper relates to Afonso, Baxa, and Slavík (2011), Ferraresi, Roventini, and Fagiolo (2014) or Bernardini and Peersman (2015) who report evidence that the size of the multiplier is significantly affected by either credit spreads, or debt overhang. We however depart from these papers in that we use a direct measure of global financial conditions (National Financial Conditions Index) and by the methodology. A second important point of departure with respect to Auerbach and Gorodnichenko (2012) relates to the treatment of the non-linearity, which relies on a Smooth Transition VAR modeling in which the switching variable is assumed to be exogenous. In this paper we explicitly model the dynamics of the interaction term —*e.g.* financial conditions— implying that they also react to the shock. We

[2]Ramey (2011) offers an alternative way of computing multipliers based on Jordà (2005) which amounts to compute a series of local projections of changes in output on changes in a variable that captures news in government spending.

[3]This view was recently challenged by Ramey and Zubairy (2014). They consider the simple regression model that relates changes in output to news about government spending, but in which they also add a non-linear component that interact these news with the slackness of the business cycle (unemployment). Using the local projection technique proposed by Jordà (2005), they then compute multipliers and found no evidence in favor of higher multipliers in bad states.

therefore rely on Generalized Impulse Function analysis à la Koop, Pesaran, and Potter (1996) to properly capture all potential effects of non-linearities.

We first estimate a VAR model for the pre–financial crisis period, stopping in 2007:IV, and recover, as in Mountford and Uhlig (2009), a business cycle shock, a monetary policy shock, a government spending shock and a government revenue shock. The business cycle and monetary shock produce the expected results. A shock to unproductive government spending that keeps government consumption above trend for 4 periods leads to a mild increase in output and consumption, but crowds out private investment. The associated short-run multipliers remain below unity, but increases over time. This is true regardless of whether total or defense government consumption is used. The results are more pronounced for productive government spending which persistently crowd out private investment. Accordingly, the associated short-run multiplier is even smaller (about one half) in the short-run, but, as predicted by theory, larger in the longer run. Again the use of total or defense spending does not alter the broad picture. The multipliers associated to labor compensation spending are found to be larger than unity on impact (of the order of 1.5) and remain above one at longer horizons, and labor compensation is not found to create any crowding out effect. The effects of a tax cut —a shock that keeps government revenues below trend for 4 periods— increases aggregate output, private consumption and total private investment. The associated multiplier is below unity in the short run, but above 3.5 after 5 years. Again these results are in line with theory, We then re-estimate the VAR over the period running from 1955:I to 2012:IV, therefore extending the sample to include the financial crisis. While the results are qualitatively left unaffected by the inclusion of the financial crisis for all shocks, they differ quantitatively. In particular, the short-run multipliers associated to both productive and unproductive government spending increase substantially. For instance, the impact multiplier associated with total government consumption is 1 on impact (0.87 in the pre-crisis period), in the case of public investment the increase is more striking (0.90 versus 0.48). The increase is even more pronounced when the focus is placed on defense spending. For instance, the multiplier on defense consumption increases by 2/3 (0.6 to 1) while the multiplier associated with defense investment is multiplied by a factor of 5. Labor compensation is, on the contrary, not affected. In the longer run —at the 5 years horizon— the opposite pattern obtains. These findings are found to be robust to the way the increase in expenditures is financed, either by letting the deficit increase or insuring a balanced budget. Note however, that while financing the increase in government spending by deficit increase usually leads to an increase in the multipliers, using a balanced budget in the first 4 quarters limits the potency of the fiscal expansion.

This suggests that the financial crisis, and the associated financial frictions, played a role in shaping the multipliers. This finding is consistent with the theoretical work of Fernández-Villaverde (2010) or Canzoneri, Collard, Dellas, and Diba (Forthcoming) which showed, in general equilibrium models, that financial conditions affect the transmission of fiscal policy. As a way to investigate this issue, we extend our set of variables to include the National Financial Conditions Index (NFCI) which is a measure of risk, liquidity and leverage in money markets and debt and equity markets as well as in the traditional and shadow banking systems. As Canzoneri, Collard, Dellas, and Diba (Forthcoming) showed, financial conditions ought to have non-linear implications for the propagation of government shocks and may induce some form of state dependence. To capture these non-linearities we estimate a non-linear version of the VAR in which the lagged variables are considered in interaction with financial conditions. Our results indicate that tighter financial conditions indeed accounts for a substantial part of the rise in the multiplier for our extended sample. For instance, we consider a shock taking place in the third quarter of 2001, when the economy faced a significant drop in cyclical output but still faced loose financial conditions, and repeat the same experiment starting the dynamics in the fourth quarter of 2008, where financial stress was high.[4] We find that moving from loose to tight financial conditions leads to an increase in the multiplier associated with a government consumption (resp. investment) shock of 25% (resp. 25%). We repeat the exercise starting again the economy in 2008:IV, but also starting from 1981:III where the economy faced similar output and financial conditions, but where the interest rate was clearly

[4]In both cases output was below trend by about about the same percentage deviation.

away from the zero lower bound. Our results then indicate that the multiplier increases further by about 40% in the case of a government consumption shock and 25% in the case of an public investment shock. We conclude that it is the interaction between monetary policy and financial constraints that explains the bulk of the increase in the multiplier.

The rest of the paper is organized as follows. In Section 1.2, we present the data and summarize the methodology we use to recover the fiscal shock. Section 1.3 presents our main results, putting some emphasis on the role of the financial crisis in the propagation of government shocks. In the lines of Mountford and Uhlig (2009), Section 1.4 offers some extensions. In particular, we consider what happens when the shocks are announced, we also investigate the role of financing in the size of the multipliers. Section 1.5 investigates the role of financial conditions in a non-linear setting. A last section concludes.

1.2 Data and Methodology

This section describes the data and the methodology we use to recover the effects of government policy shocks on macroeconomic aggregates.

1.2.1 Data

Our baseline VAR essentially replicates Mountford and Uhlig (2009) and features 10 variables.[5] We do consider several other versions of the VAR model. In particular, the main focus, as in most of the literature, is placed on the real effects of government policy shocks. To this end, the VAR features real GDP, private consumption of non-durables and services, total private investment (gross private domestic investment and durable consumption). Following Mountford and Uhlig (2009) we also include non-residential investment. Furthermore, given the potential interactions between monetary and fiscal policies, the VAR also features the federal fund rate, the GDP deflator, a measure of commodity prices and adjusted reserves.

[5]See Appendix 1.B for further details on the construction of variables.

Moreover, since one of our objective is to identify a government revenue shock we also include net taxes as a measure of government revenues to help identification. Finally, the VAR features an indicator of government spending as a way to identify the government spending shock.

We depart from the standard practice in the literature that looks at the effects of *total* government expenditures. Instead we break them into their investment and consumption components as a way to disentangle the effects of productive versus non-productive expenditures. The aim is to investigate whether disentangling the effects of various fiscal variables may be critical to understand fiscal policies.

1.2.2 Methodology

Most of the empirical literature that has attempted to recover the dynamic effects of government spending shocks on macroeconomic variables have used a linear vector autoregression (VAR) framework.[6] In this paper, these effects are also identified using a VAR of the form (abstracting from any deterministic part)[7]

$$Y_t = \sum_{i=1}^{p} A_i Y_{t-i} + u_t \tag{1.1}$$

where Y_t is a $(k \times 1)$ vector of time series, u_t is a vector of residuals satisfying $\mathbb{E}(u_t) = 0$, $\mathbb{E}(u_t u_t') = \Sigma$ and $\mathbb{E}(u_t u_{t-\tau}) = 0$ for $\tau = 1, \ldots, \infty$. The VAR is estimated using Bayesian methods. A Minnesota prior is assumed and the posterior distribution is obtained using a standard Gibbs sample (see appendix for technical details on the priors and the Gibbs sampler). Once the posterior distribution is available we use 1,000 draws from it to recover the impulse responses of the main macroeconomic aggregates to the government shock. This points to the problem of identification of the shocks and the computation of the impulse response functions.

[6]Notable exceptions are Auerbach and Gorodnichenko (2012) who use a smooth threshold vector autoregression process as a mean to acknowledge the potential state dependency of the dynamic effects of government spending shocks, or Ramey and Zubairy (2014) who favor Jordà's (2005) local projection approach also as a way to recover the state dependent effects of government spending shocks.

[7]In the application we allow for a constant and use 4 lags.

To recover a set of "fundamental" shocks, ε_t, that can be given a meaningful structural interpretation, we assume that there exists a matrix S such that

$$u_t = S\varepsilon_t \text{ with } \mathbb{E}(\varepsilon_t \varepsilon_t') = I$$

Given that the matrix S has k^2 elements whereas Σ has $k(k+1)/2$ elements, the identification of the fundamental shocks requires imposing at least $k(k-1)/2$ restrictions. Given that we are only interested in identifying a subset of the shocks we will not impose as many restrictions. It is common practice in the literature to impose short-run restrictions à la Sims (1980), or long-run restrictions à la Blanchard and Quah (1989). In this paper, we instead follow Uhlig (2005) and Mountford and Uhlig (2009) and impose sign restrictions on the impulse responses to the various shocks, which will be discussed when presenting the results. This presentation closely follows Uhlig (2005), who gives greater details in the appendix of his paper.

Uhlig (2005) shows that the matrix S can be conveniently rewritten as $S = \widetilde{S}Q$ where $\widetilde{S}$ is the Cholesky decomposition of the matrix Σ (which would correspond to imposing short-run identifying restrictions), and Q is an orthonormal matrix ($QQ' = I$). It is important to note that the matrix $\widetilde{S}$ could consist of any other convenient decomposition of the matrix Σ without affecting the results in any manner (it would just lead to an adjustment of the matrix Q). In that setting, the computation of the impulse response function to a shock can be obtained in two steps. First the set of impulse response of variable j to the i–th shock at horizon τ, denoted $\widetilde{x}^j_{i,\tau}$, is obtained for all shocks associated to the Cholesky decomposition. In that context, the impulse response function of variable j to shock s at horizon τ, $x^j_{s,\tau}$ is given by

$$x^j_{s,\tau} = \sum_{i=1}^{k} Q_{i,s} \widetilde{x}^j_{i,\tau} \tag{1.2}$$

The matrix Q is obtained by minimizing a penalty function that penalizes rotations of the Cholesky impulse matrix that do not satisfy the set of identifying restrictions we impose. More precisely, Q is given by

$$\begin{aligned} Q &= \underset{\widetilde{Q}}{\operatorname{argmin}} \, \mathcal{P}(\widetilde{Q}) \\ s.t. \ \widetilde{Q}\widetilde{Q}' &= I \end{aligned} \tag{1.3}$$

where the penalty function $\mathcal{P}$ is borrowed from Uhlig (2005) and Mountford and Uhlig (2009):

$$\mathcal{P}(Q) = \sum_{j \in J_+} \sum_{\tau=0}^{m-1} f\left(-\frac{x^j_{s,\tau}}{\sigma_j}\right) + \sum_{j \in J_-} \sum_{\tau=0}^{m-1} f\left(\frac{x^j_{s,\tau}}{\sigma_j}\right)$$

where J_+ (resp. J_-) denotes the set of variables for which the identification imposes a positive (resp. negative) response of the variable to the shock for the first m periods. Note that the impulse response function of each variable is normalized by its standard deviation as a way to avoid scale effects problem. The function $f(\cdot)$ penalizes Q matrices that do not satisfy the restrictions imposed by the econometrician.[8]

1.2.3 Identifying Assumptions

We follow closely Mountford and Uhlig (2009) in identifying the shocks. More precisely, we follow their strategy and identify *(i)* a business cycle shock, *(ii)* a monetary policy shock, *(iii)* a government spending shock and *(iv)* a government revenue shock, which are all mutually orthogonal.

The business cycle shock —shall it capture supply side or demand side phenomena— is identified as a shock that increases output, consumption, investment, and non-residential investment during the first 4 quarters following the shock. The monetary policy shock is identified as a shock that *(i)* is orthogonal to the business cycle shock and *(ii)* raises the nominal interest rate and decreases

[8]Rubio-Ramírez, Waggoner, and Zha (2010) offer an alternative approach to recover the IRFs in the case of sign restrictions, which rely on the simulation of a rotation matrix, as obtained from the QR decomposition of a randomly generated matrix. Only the draws that satisfy the sign restrictions are then kept. Using this approach rather than the penalty function approach led to very similar results.

prices and adjusted reserves in 4 quarters following the shock. Note that, the identification of these two shocks is not strictly needed to recover the fiscal shocks.[9] However, the identification of the business cycle and the monetary policy shocks proves useful as it prevents the response of macroeconomic aggregates to fiscal shocks to be contaminated by phenomena pertaining to the business cycle and/or monetary policy.

We identify two fiscal shocks: *(i)* a spending shock and *(ii)* a revenue shock. In both cases, the government spending (resp. revenue) shock is identified by restricting government spending —be it consumption or investment, or defense versus total spending— (resp. revenues) to increase in the initial 4 periods after the shock. No other variable is restricted. On the one hand, the restriction is rather weak as only the response of the government variable is used for identification. On the other hand, it is quite strong in the sense it precludes identifying a purely transient government shock or a shock that would raise, say, public spending on impact but lead to a decrease in the period that follows. As such this identification scheme, therefore, identifies shocks that indeed are persistent —not transient— positive shocks to government spending or revenues. Importantly, these two shocks are orthogonal to the business cycle and the monetary policy shocks, and are also mutually orthogonal.

1.3 Results

This section presents our main results. We first discuss the dynamic implications of the business cycle shock and the monetary policy shock. We then describe our main findings pertaining to an increase in government spending. In particular, we highlight the differences between the various types of spending and how these results are actually sensitive to the sample we use. We finally discuss the effects of a tax cut.

[9] For example, Blanchard and Perotti (2002b) directly recover the government spending shock by imposing the sole restriction that this shock shifts government spending without affecting other aggregates on impact.

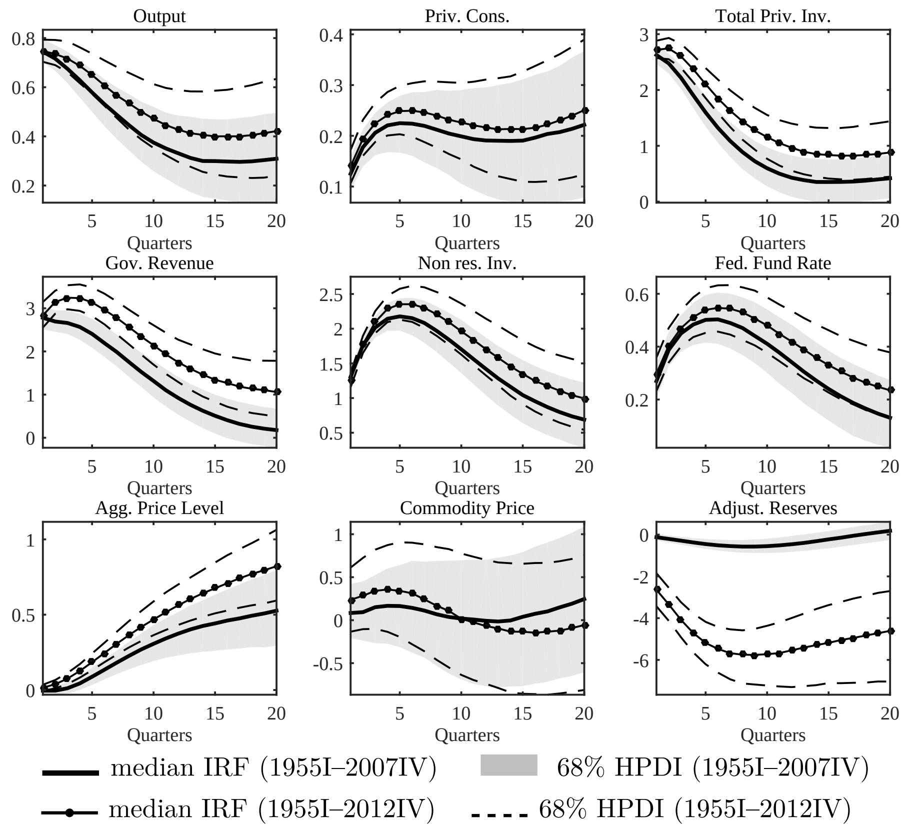
1.3.1 Non–Government Shocks

Business Cycle Shock: Figures 1.1 and 1.2 report the dynamics of the variables to a business cycle shock in each of the baseline VARs we estimated (one for each type of government spending) with a sample starting in 1955. Figure 1.1 focuses on the non-government spending variables (output, private consumption, private investment, non residential investment, the nominal interest rate, the aggregate price level, the commodity price and adjusted reserves) as obtained from a VAR featuring total government consumption as the government spending variable.[10] Figure 1.2 focuses on the response of the various types of government spending in each VAR model.

Each figure reports the median dynamics for the pre-financial crisis period (plain line), 1955I-2007IV, and for the period including the financial crisis (marked line), 1955I-2012IV. The results are reminiscent of Mountford and Uhlig (2009). By construction, output, private consumption, private investment, non-residential investment and government revenue increase on impact, and so do the federal fund rate and prices. Adjusted reserves respond negatively, which is consistent with the increase in the nominal interest rate that the price increase triggers. All responses display persistence, but only non-residential investment and the federal fund rate exhibit a hump shaped response. As expected, the response of private consumption is smaller than that of output, hence witnessing the existence of a consumption smoothing behavior, while private investment is much more responsive to the shock. Interestingly, the impulse responses reveal that the inclusion of the financial crisis in the sample makes the economy more resilient to the business cycle shock. Output, private consumption and investment and the nominal variables respond more to the shock in the whole sample than in the pre-financial crisis sample. Note, however, that the impact effect of the shock does not differ across

[10] We did not report the IRFs of the non-government spending variables across the various VARs as they do not differ significantly. These figures are available in the companion technical appendix to this paper. Also note that the similarity across VARs suggests that the identification of the business cycle shock is not sensitive to the exact specification of the fiscal side of the information set available to the econometrician.

Figure 1.1: Business Cycle Shock (Total Government Consumption VAR)



the two samples, the IRFs start to depart from each other as of the second quarter after the shock. This suggests that this difference in the responses is due more to a change in the mechanisms that propagate the shocks than to the shock itself. The behavior of adjusted reserves varies considerably across the two samples. This is largely explained by the drastic change of role played by this variable in the conduct of monetary policy during the period 2008IV-2012IV. Quantitative easing made adjusted reserves surge in that period, which led to a strong amplification of the effects of a given shock on this variable.

Figure 1.2: Business Cycle Shock: Government Spending

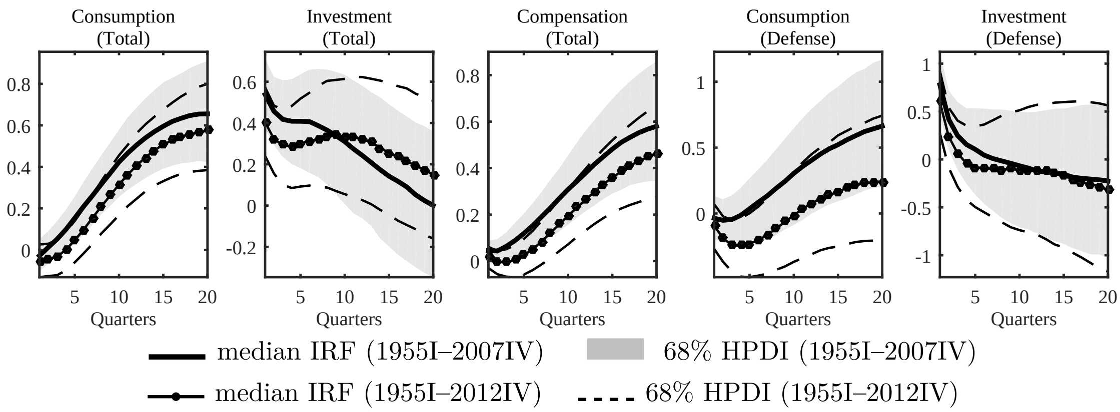


Figure 1.2 provides information on the endogenous –systematic– component of government spending as it reports how the various types of spending we consider in this paper reacts to the business cycle shock. This contains useful information regarding the formulation of a government spending rule. Figure 1.2 indicates that there exists substantial heterogeneity across such rules.

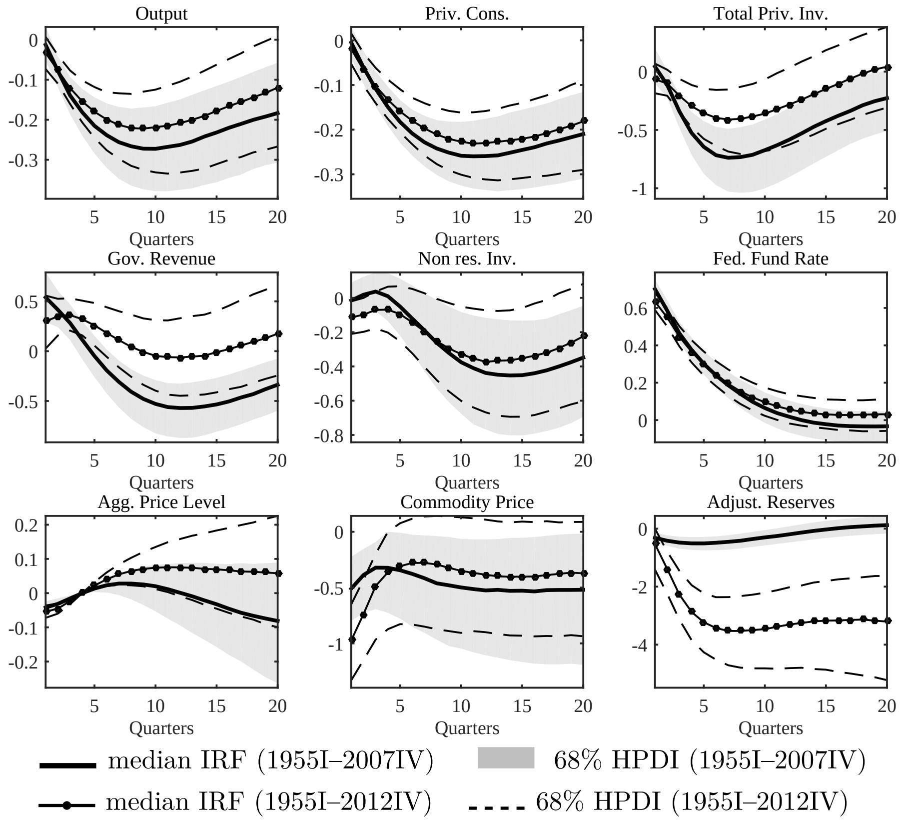
Following a positive business cycle shock, total government consumption does not respond, on impact. This is true both for total and defense consumption expenditures. After one year, government consumption reacts positively therefore suggesting that the government simply takes advantage of the increase in government revenues to increase its consumption. We obtain similar findings for the total government compensation, indicating that the government uses good times to either raise government employment and/or increase the wage of its employees. It is however worth noting that the responses of both consumption expenditures (both total and defense) and compensation do not differ across two samples. Likewise, when the sample period is restricted to start later, the impact effect of the business cycle shock on government consumption and compensation is not statistically significant from zero. The response turns positive after one and a half year in the case of consumption and about 3 years in the case of government compensation.

The results differ for government investment. The responses suggest that good times are used to increase both total and defense government investments. Productive government expenditures are therefore mostly driven by income effects rather than by stabilizing motives. However, just as for government consumption, the impact response of public investment is not affected by the inclusion of the financial crisis in the sample. When the VAR is estimated over the sample period 1980I–2007IV (or 2012IV), the median impact effect of the business cycle shock on total government investment is statistically insignificant. And, just as for consumption, the implicit investment rule followed by the government became less procyclical in the latest part of the sample.

Monetary Policy Shock: Figures 1.3 and 1.4 report the dynamics of the macroeconomic aggregates to a monetary policy shock for each specification we estimated. As in the case of the business cycle shock, we only report, in Figure 1.3, the response of the non-government spending variables in the case of a VAR featuring total government consumption as the government spending variable. Figure 1.4 focuses on the response of the various types of government spending.

Recall that, by construction, the monetary policy shock raises the nominal interest but cannot lead to an increase in prices and adjusted reserves in the first four periods following the shock. In line with the prediction of most DSGE models, a positive shift in the nominal interest rate plunges the economy in a recession; output, private consumption, private investment drop. The shock exerting a persistent effect on the interest rate, the recession also displays persistence, and the trough is reached after 10 quarters. It is also sizable as, in the pre-crisis sample, a 65 basis point increase in the nominal interest rate drives output 0.27% below trend

Figure 1.3: Monetary Policy Shock (Total Government Consumption VAR)



at the trough, which brings about a cumulative output loss of 2%. Likewise, private consumption and private investment suffer a sizable cumulative loss of, respectively, 1.7% and 5.1%. Interestingly, the presence of the financial crisis observations led to milder responses of the main aggregates, most of the shock being absorbed by prices and adjusted reserves.

Somewhat puzzling is the rise in government revenue in response to the increase in interest rates. Mountford and Uhlig (2009) report similarly that a monetary policy shock increases government revenue. A possible explanation, although not the only, is that over the sample period monetary and fiscal policy are coordinated so that a monetary tightening is accompanied by a fiscal tightening via an increase in taxes. In which case, the additional restrictions requiring monetary policy shock to be orthogonal to fiscal policy shock. They find, however, that controlling for the fiscal shock is not important for the consequences of monetary policy. [11]

Figure 1.4: Monetary Policy Shock: Government Spending

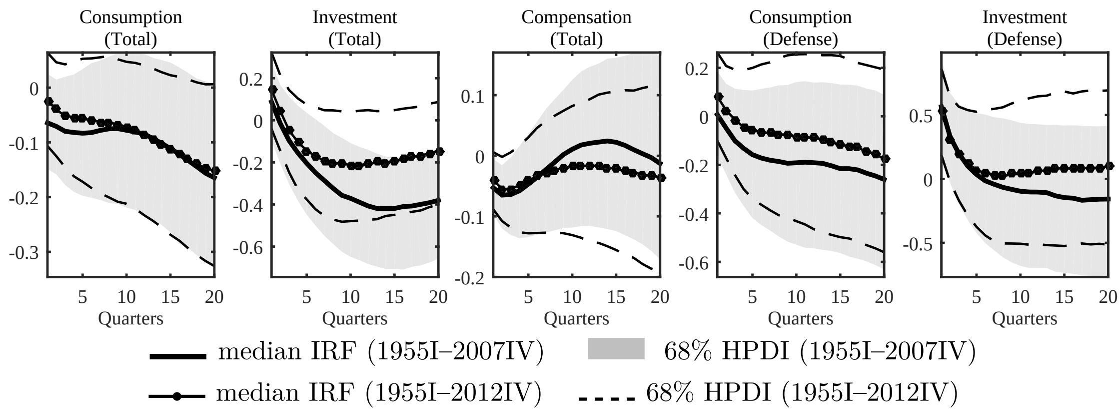


Figure 1.4 illustrates how monetary and fiscal policies interact. Total government consumption decreases following the increase in the nominal interest rate —whether the financial crisis is taken into account or not. Similar results are obtained for

[11] Mountford and Uhlig (2009) conducted robustness analysis by identifying fiscal shocks both second (orthogonal to only the business cycle shock) and third (orthogonal to both the business cycle and monetary policy shocks). They find that the responses of the real variables are very similar in both these specifications and hence any bias is small. This may be because monetary policy shocks do not appear have a large effect on real macroeconomic variables.

the defense consumption expenditures. However, the responses are not statistically different from zero. As the sample is started later, we find similar response of government spending to the monetary shock. For instance, starting the sample in 1980I implies that both government consumption and government investment drop, respectively, by 0.15 and 0.18% following a 35 basis point positive shock on the interest rate. However, they also remain statistically indifferent from zero.

1.3.2 The Government Spending Shock

This section investigates the response of the economy to a shock that raises government spending for a year. Each VAR includes a different government spending variable, which implies that the government spending shock receives a different interpretation in each case. Figure 1.5 reports the response of government spending, government revenues, output, private consumption and private investment to the shock.[12] Table 1.1 reports the associated discounted multipliers for output at horizons of 1 quarter, and then 1, 2 and 5 years, respectively. Ramey (2016) noted in her recent survey of the government spending multipliers that there exist a potential problem in the calculation of multipliers in the literature, rendering them incomparable across the studies. Specifically, researchers tend to follow Blanchard and Perotti (2002b) by calculating multipliers by comparing the *peak* output response to the *initial* government spending impact effect. Although, as noted by Ramey (2016) comparing values of impulse responses at peaks or troughs is a useful way to compare impulse responses, it is not a good way to calculate a multiplier. As argued by Ramey (2016) and Mountford and Uhlig (2009) multipliers should instead be calculated as the *present value* of the output response divided by the *present value* government spending response. This is a correct way to compute multipliers because the present value multipliers address the relevant policy question as they measure the cumulative GDP gain relative to the cumulative government spending during a given period. Thus, in this paper we follow approach suggested by Ramey (2016) and Mountford and Uhlig (2009) by computing multiplier as the ratio of the present value output and government spending responses, adjusted

[12] The full set of impulse responses can be found in the companion technical appendix.

for the average government spending share. More precisely, let us y_k^x denote the response of (log-)output to the (log-)government spending shock at horizon k and x_k denote the response of (log-)government spendings to the shock, then the discounted multiplier $m_k(y, x)$ is given by

$$m_k(y,x) = \frac{\sum_{t=0}^{k-1} \beta^k y_k^x}{\sum_{t=0}^{k-1} \beta^k x_k} \times \left(\frac{\overline{y}}{\overline{x}}\right)$$

where $\beta \in (0,1)$ is the discount factor,[13] $\overline{x}/\overline{y}$ denotes the average share of government spending x in total output.

Panel (a) of Figure 1.5 displays the dynamics of the main aggregates to a positive shock to total government consumption. Output responds positively on impact, although the response is mild. One standard interpretation of this positive response in the business cycle literature is related to the existence of an associated *negative* wealth effect which makes the agents anticipate higher tax rates in the future –as a way for the government to finance its consumption– which in turn prompts agents to increase their labor supply and hence aggregate output. However, neither the response of government revenue nor that of consumption do sustain this mechanism. Government revenues fall on impact while private consumption mildly increases on impact. Should the negative wealth effect drive the result, the opposite pattern in the response of the two latter aggregates should be observed. This, however, does not mean that government consumption does not exert any form of crowding out. Private investment decreases on impact and remains below trend for 1 year. These responses –in particular the positive response of consumption– are reminiscent of earlier findings by Galí, López-Salido, and Vallés (2007) and might be explained by a model featuring nominal rigidities and rule-of-thumb consumers à la Mankiw (2000) or a model in which household cannot observe perfectly the shocks (see Canzoneri, Collard, Dellas, and Diba (2012)). Once we consider the financial crisis, we find that for the shocks to total government consumption and government compensation the responses across both samples are remarkably close. Some differences do emerge, but not particularly large, when we consider other three shocks (notably, government investment, defense consumption and defense

[13]In practice we use the average effective real interest rate over the sample to compute $\beta = \frac{1}{1+r}$.

investment shocks).

Panel (b) of Figure 1.5 reports the dynamics of aggregates following a positive shock to government labor compensation.[14] The results are very similar to those in the case of government consumption. Output and consumption mildly increase in the short-run and continue to do so in the next few years. It is worth noting that the crowding-out effect that government consumption exerted on private investment is mitigated when the shock hits labor compensation. Interestingly, the dynamics of the government wage bill differs substantially from government consumption as it displays a clear hump-shaped pattern, which the government's willingness to smooth its wage bill.[15] The multiplier associated with the wage bill is higher than those of the government consumption. A key difference emerges from the two experiments. The multipliers associated with government compensation are essentially not affected by the inclusion of the financial crisis in the sample. In fact the response of output to the government compensation shock is left virtually unaffected. The reaction of the wage bill to a shock is milder and less persistent. One potential interpretation of this result is that the financial crisis somehow imposed some discipline on the government and called for a better control of the wage bill. An alternative interpretation, although non exclusive, is that the financial crisis may have weakened the outside options of the employees during the wage bargaining process.[16]

Panel (c) of Figure 1.5 plots the impulse response of the economy following a positive shock to total government investment, hence shedding light on the role of productive government expenditures over the business cycle. Just as government consumption, government investment exerts a positive effect on output and private consumption in the short-run. However, their response is small, as reflected in

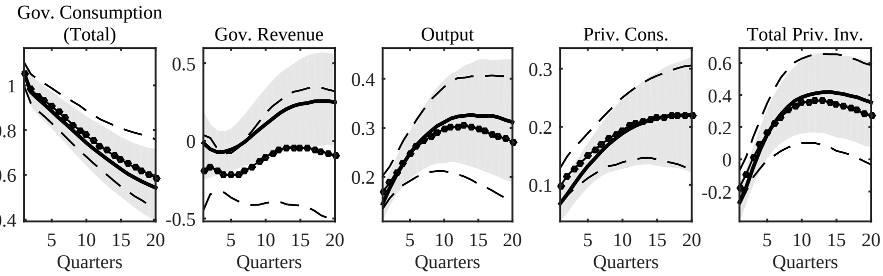
[14]In this experiment, we do not take a stand on whether the government increases the number of its employees, or the wage it pays to its employees, but rather investigate the effects of an increase in government's *total* wage bill.

[15]An alternative explanation is based on the existence of trade unions that protect the employment of their members while using their bargaining power to smooth the real wage.

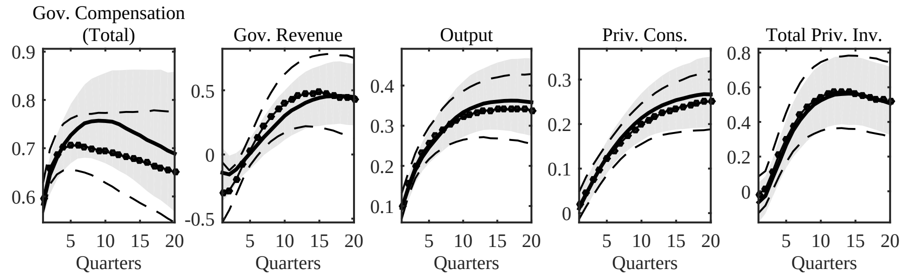
[16]Note however that these interpretations are rather speculative as the identification procedure does not permit to recover the mechanism that underlies these responses.

Figure 1.5: Government Spending Shock

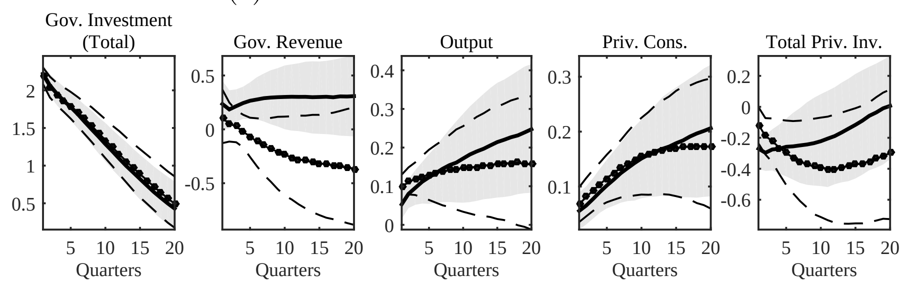
(a) Total Government Consumption



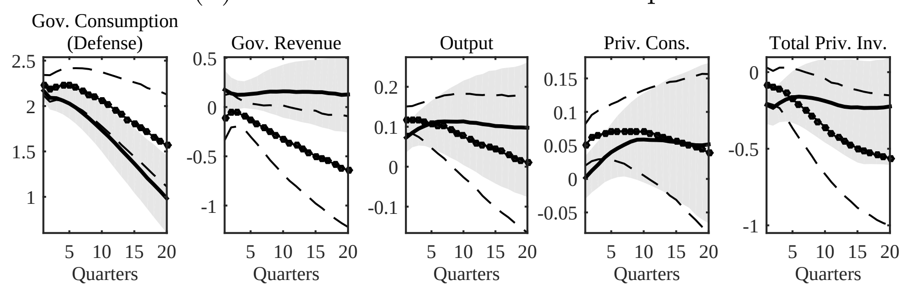
(b) Total Government Compensation



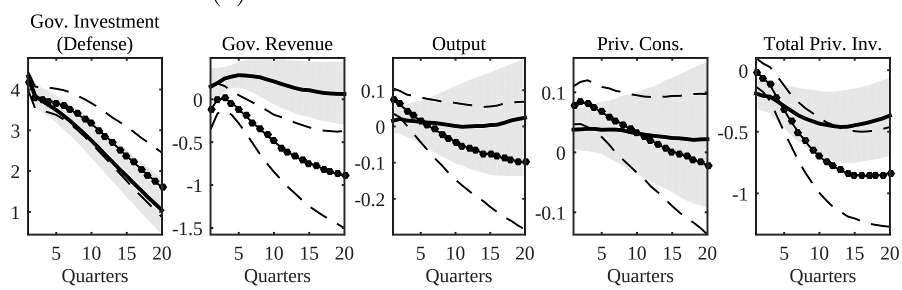
(c) Total Government Investment



(d) Defense Government Consumption



(e) Defense Government Investment



median IRF (1955I–2007IV) 68% HPDI (1955I–2007IV)
median IRF (1955I–2012IV) 68% HPDI (1955I–2012IV)

the size of the impact multiplier which is clearly below unity — 0.5 in the pre-crisis sample. In other words there is no such thing as a productive government spending multiplier in the short-run. The main reason for this finding is found in the crowding-out effect that public investment has on private investment (see right panel of panel c). The effects of a government investment shock become more potent as the horizon increases. For instance, at the horizon of 5 years, the discounted multiplier for productive expenditures is larger than for consumption (2.7 versus 2.3), which is in line with previous findings by Baxter and King (1993) in a real business cycle type of model and the associated positive wealth effect productive spending traditionally exert in this class of models. Like for the other types of expenditures, the inclusion of the financial crisis in the sample somewhat alters the properties of the dynamics. More precisely, while output and –to a lesser extent– consumption respond more favorably to the shock in the short-run, the longer-run effect on output and consumption is substantially weakened. For instance, output increases by 0.1% on impact in the crisis sample (0.05% in the pre-crisis period). After 1 year, public investment crowds out private investment by more when the financial crisis is taken into account. In the short-run, taking into account the financial crisis dampens the negative response of private investment to the public investment shock –therefore limiting the crowding out effect. However, the long-run effect on output is not statistically different from zero.

Panel (d) of Figure 1.5 reports the dynamics of aggregates following a positive shock to defense government consumption. The responses are very similar to those obtained for the total government consumption shock.[17] In the presence of financial crisis, the impact response of the government consumption variable remains the same across the two samples, the short-run response of output increases in the crisis period. This is confirmed by size of the impact and 1 year ahead discounted multipliers. When the financial crisis is excluded from the sample, the impact

[17] Defense government consumption is usually considered to be less sensitive to the business cycle and therefore closer to be exogenous than total government consumption. In our sample both display very similar properties. For instance the correlation between HP-filtered output and government consumption for the period 1955I-2007IV (resp. 1955I-2012IV) is -0.03 (resp. -0.12) for total consumption and -0.08 (resp. -0.15) in the case of defense consumption.

multiplier on output is 0.87 (1.22 at the 1 year horizon). Bringing back information about the financial crisis the multiplier raises to 1 (1.27 at the 1 year horizon). The increase in the multiplier is more pronounced in the case of defense consumption expenditures going from 0.59 in the pre-crisis sample to 0.96 as the financial crisis is included.[18] However, as for the total government investment shock the long-run effects on the output are not statistically significant for the financial crisis period.

There are essentially two candidate explanations to this change in the size of the multiplier as we include the crisis; *(i)* the share of the government consumption in output spending decreased and/or *(ii)* the propagation mechanisms were affected by the crisis. The first explanation is not supported by the data. For instance, in the pre-crisis period the total (resp. defense) government consumption share was 16% of GDP (resp. 5.7%), and it remains at 16% (resp. 5.6%) when the crisis is included in the sample. This therefore points more to an explanation based on a change in the propagation mechanisms induced by the crisis itself and/or the reaction of monetary policy to the crisis.[19] Indeed, while the response of total government consumption is left essentially unaffected by the inclusion of the financial crisis, the response of output is slightly larger on impact (0.14% versus 0.17%). Note that even though the inclusion of the financial crisis in the sample leads to an increase in the multiplier in the short-run, the multiplier remains below unity, which is in line with previous recent findings (see, among others,Mountford and Uhlig (2009) in a linear setting, and Ramey and Zubairy (2014) in a setting taking state dependence into account).[20] In the longer run, the results reverse and the crisis sample shows a smaller multiplier at the 5 years horizon than the pre-crisis sample. The main reason for this result is that the inclusion of the financial crisis in the sample makes output revert faster (see panel (a) of the figure).

To summarize, we consistently find a positive effect of public spending on

[18]The next section will investigate more systematically the sensitivity of the multipliers to the sample.

[19]This view is actually supported by the change in the behavior of adjusted reserves in the crisis sample that we already discussed in the previous section.

[20]Auerbach and Gorodnichenko (2012) challenge these findings and argue, using a Smooth Transition VAR model, that the multiplier increases dramatically during recessions.

Table 1.1: Government Spending Discounted Multipliers

	1955I–2007IV				1955I–2012IV			
	Impact	1 Year	2 Years	5 Years	Impact	1 Year	2 Years	5 Years
				Output				
Total Government								
C	0.87	1.22	1.59	2.36	1.00	1.27	1.57	2.14
	[0.76, 1.00]	[0.94, 1.56]	[1.25, 1.89]	[1.74, 2.68]	[0.74, 1.41]	[1.11, 1.34]	[1.17, 2.04]	[1.37, 2.35]
W	1.58	2.45	3.09	4.08	1.62	2.55	3.25	4.18
	[1.18, 1.84]	[2.07, 3.30]	[0.72, 4.38]	[2.22, 5.78]	[0.92, 2.28]	[1.78, 3.38]	[2.62, 4.18]	[3.52, 5.38]
I	0.48	0.81	1.20	2.63	0.90	1.12	1.35	2.19
	[-0.18, 1.34]	[0.11, 1.23]	[0.92, 1.98]	[1.22, 3.11]	[0.08, 1.69]	[-0.11, 2.28]	[-0.32, 2.68]	[-0.24, 4.78]
Defense Component								
C	0.59	0.74	0.87	1.09	0.96	0.93	0.89	0.64
	[0.09, 1.12]	[0.26, 1.18]	[0.62, 1.68]	[-0.43, 2.21]	[0.33, 1.43]	[0.48, 1.28]	[0.55, 1.18]	[-0.13, 1.38]
I	0.20	0.23	0.19	0.19	0.99	0.76	0.36	-0.60
	[-0.02, 0.64]	[-0.13, 0.91]	[-0.11, 0.58]	[-0.12, 0.57]	[0.43, 1.13]	[-0.38, 1.51]	[-0.13, 0.81]	[-0.78, 0.13]
				Private Consumption				
Total Government								
C	0.22	0.32	0.45	0.77	0.32	0.41	0.53	0.78
	[0.09, 0.44]	[0.18, 0.66]	[0.31, 0.81]	[0.19, 1.07]	[0.14, 0.83]	[0.24, 0.91]	[0.11, 0.91]	[0.38, 1.13]
W	0.09	0.45	0.80	1.39	0.16	0.47	0.80	1.38
	[0.01, 0.44]	[0.11, 0.97]	[0.12, 0.95]	[0.57, 1.99]	[0.03, 0.73]	[0.31, 0.91]	[0.03, 1.11]	[0.77, 1.93]
I	0.26	0.38	0.55	1.18	0.34	0.47	0.64	1.18
	[0.12, 0.66]	[0.15, 0.84]	[0.17, 0.78]	[0.72, 1.47]	[0.13, 0.93]	[0.28, 1.01]	[0.43, 0.91]	[0.98, 1.73]
Defense Component								
C	0.01	0.08	0.15	0.25	0.22	0.27	0.29	0.29
	[-0.22, 0.64]	[-0.42, 0.51]	[-0.10, 0.58]	[-0.12, 0.67]	[-0.23, 0.93]	[-0.18, 0.91]	[-0.23, 0.90]	[-0.28, 0.73]
I	0.26	0.29	0.30	0.36	0.57	0.62	0.56	0.32
	[-0.08, 0.58]	[-0.10, 0.73]	[-0.10, 0.56]	[-0.18, 0.77]	[0.23, 0.83]	[-0.28, 0.91]	[-0.17, 0.94]	[-0.18, 0.73]

Note: Y: Output, C: consumption, I: Investment, W: Labor Compensation. Median multipliers and in brackets confidence interval 16th, 84th quantiles output and private consumption, but a marked crowding out effect on private investment. Accordingly discounted multipliers are less than unity in the short run for all types of expenditures, but are significantly larger for consumption spending than for investment spending in the short-run. On the contrary, in the longer run, investment spending exhibits a larger discounted multiplier possibly due to the associated positive wealth effect. Another important finding from the analysis is that the size of multipliers, for government spending and compensation shocks, is affected by the inclusion of the financial crisis in the sample. However, for the government investment and defense shocks the inclusion of financial crisis has no statistically significant effect.

A potential reason for larger effect, in case of government spending and compensation shocks, is that by shifting the ending date of the sample forward, more weight is given to the information pertaining to the financial crisis. Hence, if it is indeed the case that, as argued by Eggertsson (2010), Christiano, Eichenbaum, and Rebelo (2011) or Erceg and Lindé (2014), fiscal multipliers are much larger at the zero lower bound,[21], then multipliers are indeed expected to raise as the sample gives greater weight to the recent financial crisis where nominal interest rates have been driven to zero. This actually prompts to the question of the importance of the sample for the transmission of government shocks and their associated multipliers.

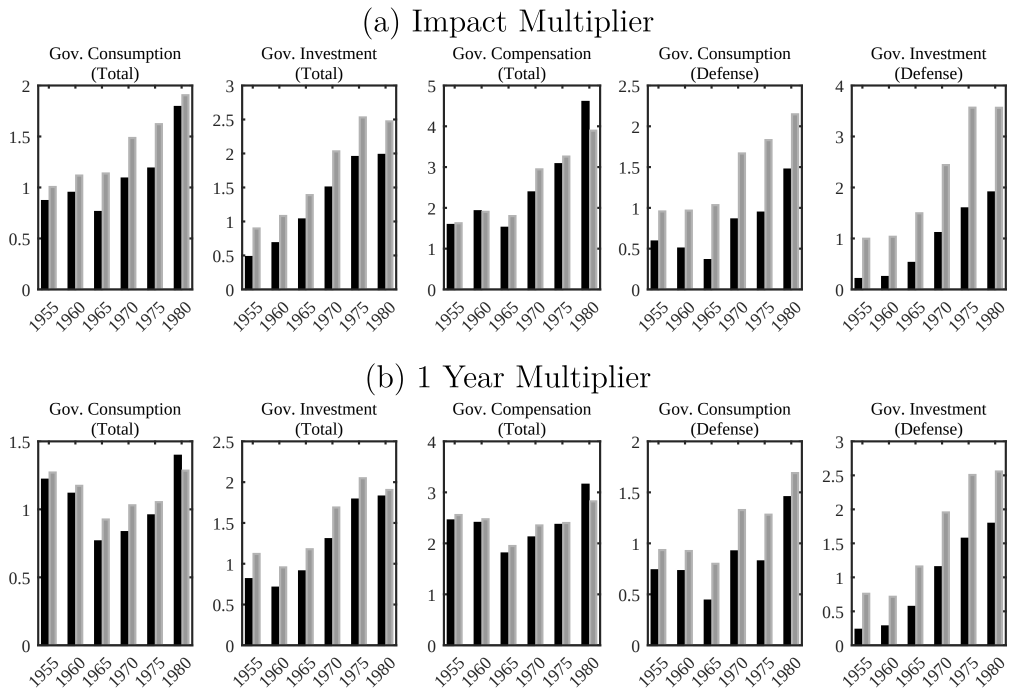
In order to tackle this question, Figure 1.6 reports the level of discounted multipliers at various horizon when the sample is started from various years[22] and ends either in the last quarter of 2007 (pre-crisis sample) or in the last quarter of 2012 to include the financial crisis. The plain dark line corresponds to the level of the multiplier attained in the pre-crisis sample, the gray one in the whole sample. The exercise is repeated for each type of public expenditures. Figure 1.6 first indicates that, for all types of government spending –to the notable exception of

[21] Halrom and Sarte (2014) and Braun and Körber (2014) however show that multipliers in a liquidity trap depends on many modeling details. The existence of a liquidity trap therefore does not guarantee, theoretically, the existence of large multipliers. In a quantitative new Keynesian model, Cogan, Cwik, Taylor, and Wieland (2010) find no evidence favoring a positive role of the zero lower bound on the size of the multiplier.

[22] The sample is started from the first quarter of each of the specified year.

government compensation– including the financial crisis magnifies the short-run discounted multipliers, whatever the initial dates of the sample is. The increase in the impact multiplier is more pronounced as the starting date of the sample increases. However, this cannot be the whole story. Indeed, as can be seen from the figure, impact multipliers (and to a large extent the 1 year multipliers) also increase in the pre-crisis sample.

Figure 1.6: Multipliers over Time

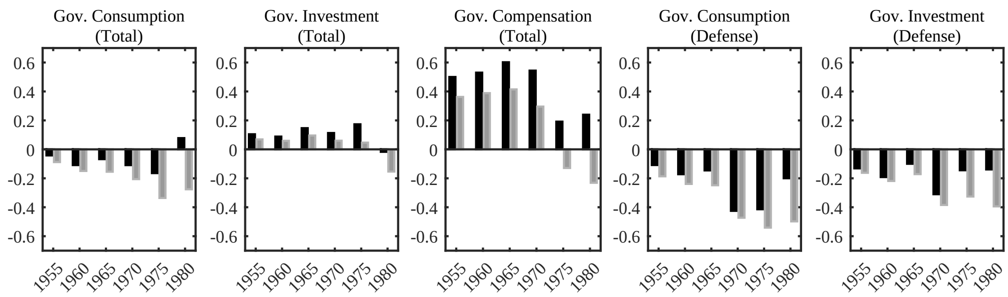


▌ T_0–2007IV, ▌ T_0–2012IV, where T_0 denotes the starting date of the sample (reported on the x-axis).

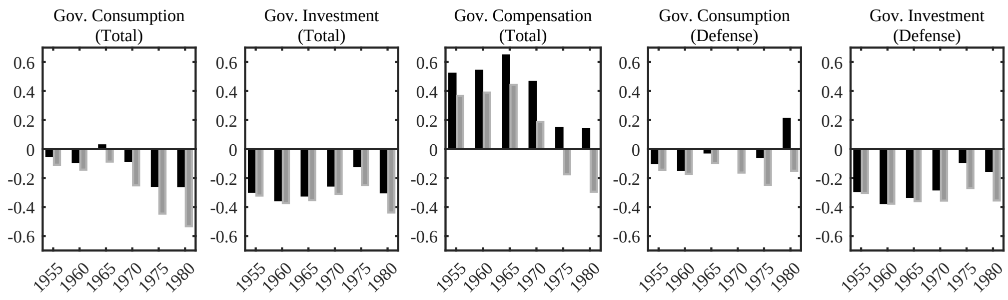
The multiplier associated to total government consumption varies from 0.87 when the sample is started from 1955 to 1.8 when the sample starts in 1980 — which therefore restricts the sample to the post-Volcker period. In fact, as the starting date of the sample is shifted forward, more weight is put on the post-Volcker period in the sample, and hence on inflation stabilization. Inspection of the IRFs of the aggregate price level to the government consumption shock (not reported) confirms it. For instance, the median impact effect of government consumption shock in the 1980I-2007IV sample is three times smaller than in the 1955I-2007IV sample. In a new Keynesian framework, greater price sluggishness leads to greater adjustments of quantities. This view is supported by the data as the median impact response of output increases by 22%. In that context, the government consumption multiplier increases. This way of interpreting the results pushes the view that the endogenous part of monetary policy created favorable conditions for enhancing the potency of fiscal policy. However, part of the increase in the multiplier should also be found in the fiscal policy rule itself. In particular, the larger the degree of countercyclicality of the government rule, the larger the multiplier should be. Figure 1.7 reports the correlation between the cyclical component of

Figure 1.7: Cyclicality of Government Spending

(a) Contemporaneous Correlation: $\mathrm{Corr}(g_t^{\mathrm{HP}}, y_t^{\mathrm{HP}})$



(b) 1 Year Correlation: $\mathrm{Corr}(g_t^{\mathrm{HP}}, y_{t+4}^{\mathrm{HP}})$



T_0–2007IV, T_0–2012IV, where T_0 denotes the starting date of the sample (reported on the x-axis).

government spending and the cyclical component of output.[23] Panel (a) of the figure reports the contemporaneous correlation, Panel (b) the correlation where output was led by 1 year. As can be seen from Panel (a) of the figure, total government consumption dynamics is more countercyclical as the starting date is shifted forward –the phenomenon being even more pronounced as the financial crisis is included in the sample. This countercyclical behavior of government consumption is actually more pronounced for defense purposes consumption. The same greater countercyclical behavior of government consumption can be observed for the 1 year ahead correlation, hence explaining the increase of the discounted multiplier at the 1 year horizon. A similar pattern obtains for government compensation –although it is not countercyclical for the 50's and the 60's. The correlation between output and government compensation decreases over time (and becomes negative when the sample is started in the 70's onward). This lower correlation witnesses that the positive systematic link between the government wage bill and output is somehow broken, which implies the compensation of government employees can have been used more effectively to stimulate activity.

The multipliers associated to government investment, be it total or for defense purposes, also increase as the starting date of the sample is shifted forward. For instance, in the pre-crisis sample the median impact multiplier is 0.5 does not exhibit countercyclical behavior (except for the post-Volcker sample). Its contemporaneous correlation with output also becomes more negative in the whole sample as the sample initial date is shifted forward, which reveals again that greater countercyclicality is associated with greater multipliers. The results are less supportive of this view in the pre-crisis period suggesting that alternative mechanisms can also be at work. In Section 1.5 we suggest that part of the explanation can be found in the presence of financial frictions.

[23] The cyclical component is obtained by applying the bandpass filter of Christiano and Fitzgerald (2003) for frequencies ranging from 6 to 32 quarters.

1.3.3 The Government Revenue Shock

We now investigate the implications of a tax cut for the economy. Figure 1.8 reports the dynamics of government revenues, output, private consumption and investment for the sample 1955:I-2012:IV. We only report the dynamics as estimated from the model featuring total government consumption as the results for the other models are very similar.[24] Table 1.2 reports the associated discounted multipliers for output at horizons of 1 quarters, and of 1, 2 and 5 years. In the case of a cut in government revenue, following Ramey (2016) and Mountford and Uhlig (2009), the multiplier $m_k(y,\tau)$ is computed as

$$m_k(y,\tau) = -\frac{\sum_{t=0}^{k-1} \beta^k y_k^{\tau}}{\sum_{t=0}^{k-1} \beta^k \tau_k} \times \left(\frac{\overline{y}}{\overline{\tau}}\right)$$

where $\overline{\tau}/\overline{y}$ denotes the average share of government revenue in total output.

Table 1.2: Government Revenue Multipliers

1955I–2007IV				1955I–2012IV			
Impact	1 Year	2 Years	5 Years	Impact	1 Year	2 Years	5 Years
0.61	1.01	1.81	3.79	0.53	1.02	1.98	2.52
[0.22, 0.97]	[0.33, 1.72]	[0.51, 2.58]	[2.92, 4.77]	[0.23, 1.03]	[0.98, 1.41]	[1.13, 2.51]	[1.77, 3.03]

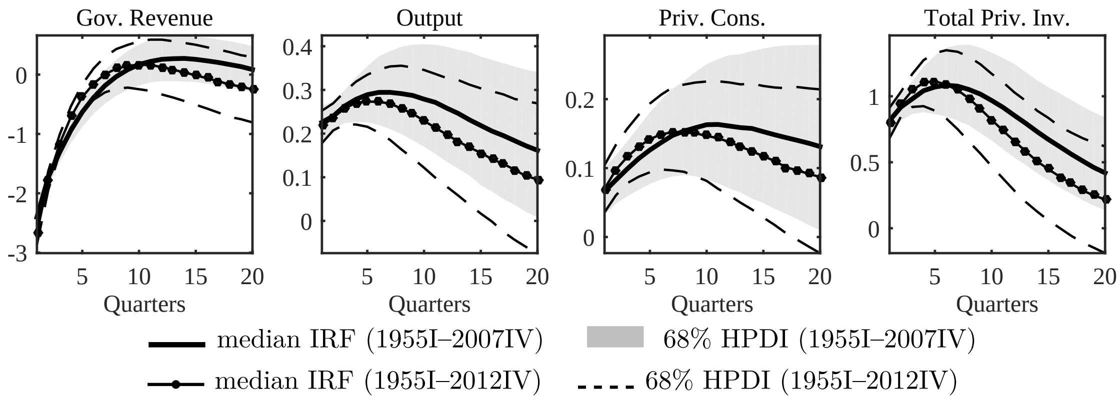
Note: Median multipliers and 68% HPDI

As indicated in the Figure 1.8, the cut in government revenue frees up some resources for the private sector. Output, private consumption and investment (including non-residential investment) all increase on impact; it is also worth noting that, in all VARs, the measure of government spending co-moves positively with output. Government revenue remains below trend during 8 periods, which translates into a persistent boom in the economy. Consequently, the responses of output, consumption and investment also display persistence and all exhibit hump-shaped

[24] The interested reader is referred to the companion appendix for the IRFs obtained from the other models.

dynamics with a peak in the IRF of output (resp. investment and consumption) 7 quarters (resp. 5 and 10 quarters) after the shock. The associated short-run multiplier is clearly below unity (0.61 on impact), and it only reaches unity after one year thereby reflecting the hump-shaped behavior of the response of output to the tax cut. The positive effects of the tax cut materialize in the longer run, as, for instance, the multiplier reaches 3.8 after 5 years.

Figure 1.8: Government Revenue Shock



The inclusion of the financial crisis in the sample has very little consequences for the dynamics of output in the short run. However, after one year, output starts being less responsive than in the pre-crisis sample. This translates into very similar short-run multipliers across the two samples (0.61 in the pre-crisis sample versus 0.53 in the crisis sample). Differences emerge as the time horizon increases, and after 5 years the multiplier in the pre-crisis period is 50% greater than when the financial crisis is included (3.80 versus 2.5). One potential interpretation of this result is that the private resources that are now available to the private agents in the economy cannot be allocated efficiently due to financial frictions, which leads to a relative loss of output — accompanied with a relative loss of consumption and investment due to the negative wealth effect created by the mis-allocation of resources — in the longer run.

1.4 Extensions

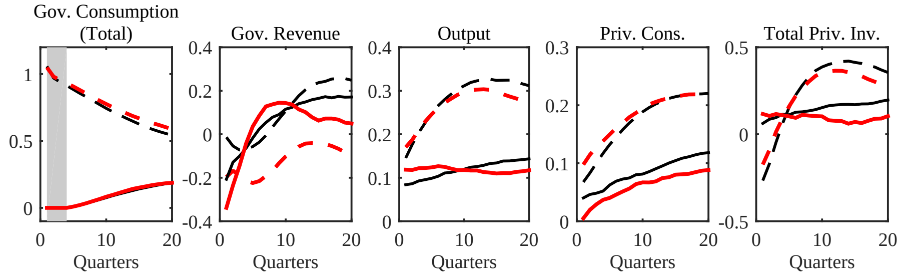
This section offers some extensions to the baseline results, focusing essentially on the public spending. In particular, we investigate the role of the announcement of public expenditures for the propagation of fiscal shocks. We also assess the role of the financing of the public spending.

1.4.1 The Role of Announcements

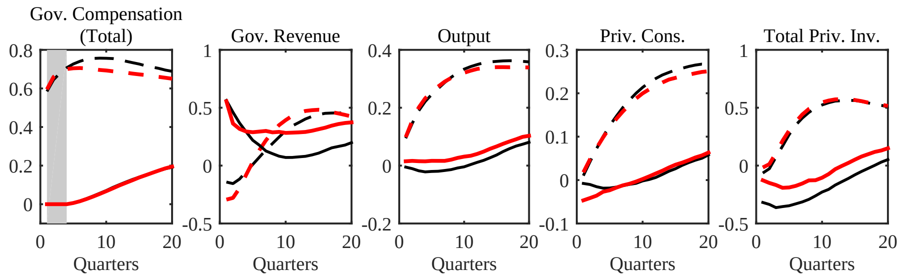
Figures 1.9 and 1.10 compare the average dynamic responses of aggregates to the various government spending shocks under two alternative timing of announcement. The first one corresponds to our previous baseline experiment, the shock is unannounced and surprises the agents. In the second, the shock is announced one year before it effectively hits the economy. One striking result that emerges from the figure is that, contrary to the case of an unannounced shock, the government spending variable reacts gradually after the first four quarters and builds up over time. Also, note that the inclusion of the financial crisis does not affect the response of government spending, implying that any difference in the response of macroeconomic aggregates can only be due to a change in the propagation mechanisms during that period. The main conclusion that can be drawn from the figure is that the announcement of the shock —by giving the agents the opportunity to smooth out its effects— reduces its effects on output and consumption. Interestingly, restricting attention to defense spending –either its consumption or investment– leads to a drop in both output and consumption, which is even more pronounced when the financial crisis is included in the sample. As in Mountford and Uhlig (2009), the announcement of the shock also mitigates the crowding out effect on investment (except in the case of government compensation shock). Finally, once the crisis is included in the sample, the positive effects on the output and private consumption of the announced government consumption and investment shocks are much milder than in the pre-crisis sample. For the announced defense spending shocks the negative effect on the output and private consumption are more pronounced than in the pre-crisis sample. But the financial

Figure 1.9: Announced Government Spending Shock (I)

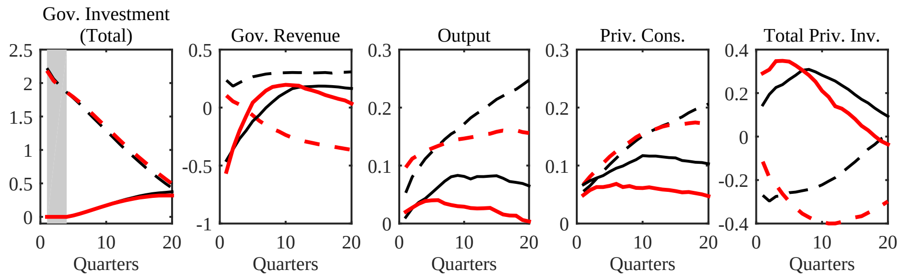
(a) Total Government Consumption



(b) Total Government Compensation



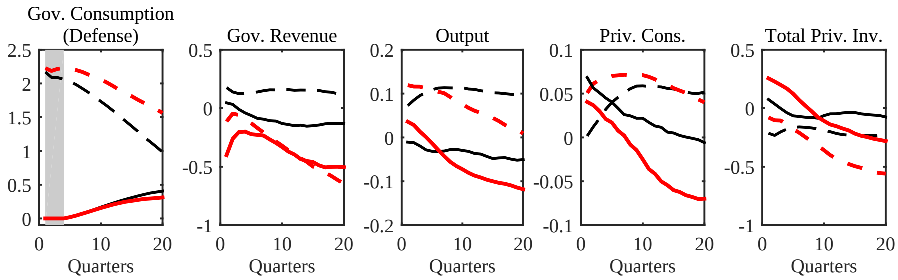
(c) Total Government Investment



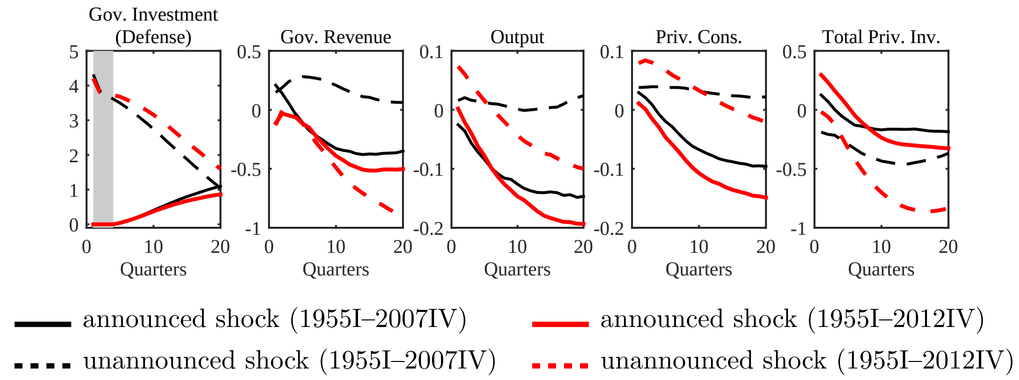
announced shock (1955I–2007IV) announced shock (1955I–2012IV)
unannounced shock (1955I–2007IV) unannounced shock (1955I–2012IV)

Figure 1.10: Announced Government Spending Shock (II)

(d) Defense Government Consumption



(e) Defense Government Investment



crisis, however, have no significant effect on the output and private consumption for the announced government compensation shock.

1.4.2 The Role of Financing

In this section, we investigate how the response of the economy and the multipliers are affected by the way a one year 1% increase of public expenditures is financed. We consider two ways of financing these expenditures. In the first one, we assume that the increase in public expenditures is fully financed by adjusting the deficit. Following Mountford and Uhlig (2009), we implement this restriction by assuming that government revenues are held constant in the first four period following the shock. In the second one, we assume that the government makes sure that the increase in public spending is neutral for the budget. This is achieved by assuming that tax revenues vary so as to balance the increase in government spending in the first four periods following the shock. These restrictions can be simply implemented by combining the impulse responses of aggregate variables to the government spending and revenue shocks. One just need to recover weights α_k and β_k, $k = 1, \ldots, 4$, that *(i)* ensures that government spending is 1% above trend during the initial 4 quarters, and *(ii)* that deviations of tax revenue (resp. tax revenue net of government spending) from their long run trend are identically 0 during 4 quarters. For instance, in the case of the deficit financing restriction, the weights α_k and β_k solve

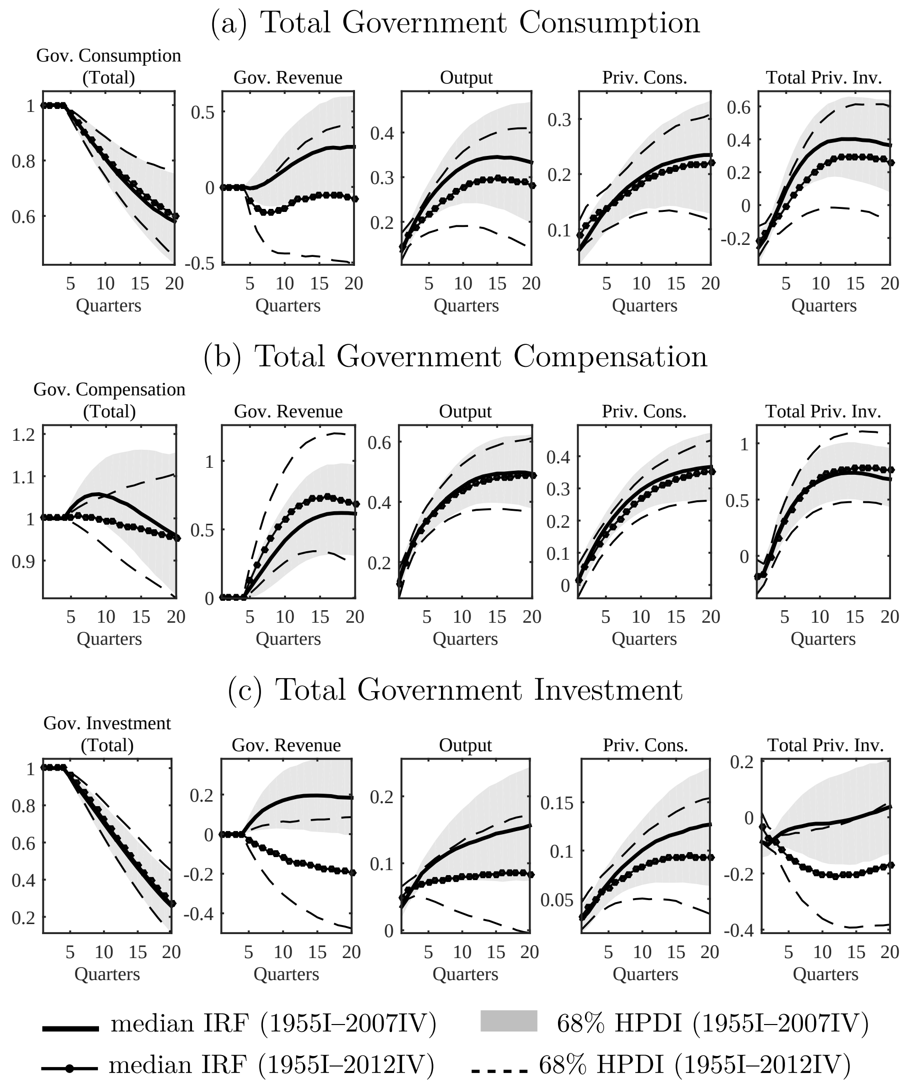
$$\sum_{k=1}^{4} \alpha_k G_{g,4-\tau} + \beta_k R_{g,4-\tau} = 1$$
$$\sum_{k=1}^{4} \alpha_k G_{r,4-\tau} + \beta_k R_{r,4-\tau} = 0$$

where $\widetilde{G}_{s,\tau}$ (resp. $\widetilde{R}_{s,\tau}$) denotes the response of government spending (resp. revenue) to shock $s = g, r$ at horizon τ. In the case of the balanced budget restriction, the second equation reads

$$\sum_{k=1}^{4} \alpha_k G_{r,4-\tau} + \beta_k R_{r,4-\tau} = \overline{G}/\overline{R}$$

where $\overline{G}/\overline{R}$ denotes the average government spending to revenue ratio.[25] Figures 1.11–1.14 report the dynamics to a government spending shock assuming that the shock is purely financed by increasing the deficit, or constraining the revenue to balance the budget. Table 1.3 reports the associated discounted multipliers.

Figure 1.11: Government Spending Shock: Deficit (I)



[25]This expression can actually be derived from the log-linear version of the definition of deficit ($D_t = G_t - R_t$), which reads $\frac{D}{R}\widehat{d}_t = \frac{G}{R}\widehat{g}_t - \widehat{r}_t$. A balanced budget then imposes $\widehat{d}_t = 0$.

Table 1.3: Government Spending Discounted Multipliers

	1955I–2007IV				1955I–2012IV			
	Impact	1 Year	2 Years	5 Years	Impact	1 Year	2 Years	5 Years
Total Government Consumption								
A	0.87	1.22	1.59	2.36	1.00	1.27	1.57	2.14
	[0.76, 1.00]	[0.94, 1.56]	[1.25, 1.89]	[1.74, 2.68]	[0.74, 1.41]	[1.11, 1.34]	[1.17, 2.04]	[1.37, 2.35]
D	0.84	1.15	1.50	2.28	0.91	1.09	1.35	1.95
	[0.46, 1.03]	[0.98, 1.62]	[1.15, 1.78]	[1.66, 2.56]	[0.63, 1.33]	[0.91, 1.15]	[1.03, 1.81]	[1.55, 2.23]
B	0.23	0.21	0.32	1.00	0.35	0.19	0.18	0.84
	[-0.07, 0.67]	[-0.01, 0.61]	[-0.15, 0.75]	[-0.77, 1.66]	[-0.13, 0.53]	[-0.02, 0.45]	[-0.03, 0.71]	[-0.55, 1.43]
Total Government Compensation								
A	1.58	2.45	3.09	4.08	1.62	2.55	3.25	4.18
	[1.18, 1.84]	[2.07, 3.30]	[0.72, 4.38]	[2.22, 5.78]	[0.92, 2.28]	[1.78, 3.38]	[2.62, 4.18]	[3.52, 5.38]
D	1.36	2.25	2.92	3.93	1.22	2.16	2.89	3.94
	[1.04, 1.61]	[1.97, 2.95]	[0.68, 4.08]	[2.03, 5.38]	[0.56, 1.87]	[1.33, 2.97]	[2.22, 3.77]	[3.27, 5.01]
B	0.79	1.45	2.01	3.07	0.67	1.35	1.99	3.26
	[0.44, 1.12]	[1.07, 1.95]	[1.80, 2.26]	[2.83, 3.31]	[0.31, 1.05]	[1.03, 1.67]	[1.42, 2.67]	[2.88, 3.69]
Total Government Investment								
A	0.48	0.81	1.20	2.63	0.90	1.12	1.35	2.19
	[-0.18, 1.34]	[0.11, 1.23]	[0.92, 1.98]	[1.22, 3.11]	[0.08, 1.69]	[-0.11, 2.28]	[-0.32, 2.68]	[-0.24, 4.78]
D	0.70	1.19	1.73	3.40	0.99	1.22	1.43	2.19
	[0.33, 1.04]	[0.53, 1.65]	[1.41, 2.51]	[0.62, 3.93]	[0.03, 1.80]	[-0.09, 2.41]	[-0.70, 2.88]	[-1.55, 3.79]
B	0.00	0.04	0.12	0.98	0.30	0.08	−0.11	0.25
	[-0.13, 0.15]	[-0.35, 0.40]	[0.01, 0.27]	[0.32, 1.63]	[-0.13, 0.54]	[-0.18, 0.34]	[-0.20, 0.32]	[-0.25, 0.47]
Defense Government Consumption								
A	0.59	0.74	0.87	1.09	0.96	0.93	0.89	0.64
	[0.09, 1.12]	[0.26, 1.18]	[0.62, 1.68]	[-0.43, 2.21]	[0.33, 1.43]	[0.48, 1.28]	[0.55, 1.18]	[-0.13, 1.38]
D	0.73	0.94	1.11	1.38	0.86	0.83	0.75	0.49
	[0.29, 1.13]	[0.47, 1.39]	[0.85, 1.94]	[-0.74, 2.53]	[0.24, 1.34]	[0.38, 1.17]	[0.41, 1.04]	[-0.10, 0.98]
B	0.02	−0.16	−0.33	−0.33	0.19	−0.24	−0.65	−0.93
	[-0.13, 0.16]	[-0.37, 0.14]	[-0.54, 0.11]	[-0.55, 0.25]	[-0.03, 0.38]	[-0.64, 0.21]	[-1.05, 0.44]	[-2.15, 1.11]
Defense Government Investment								
A	0.20	0.23	0.19	0.19	0.99	0.76	0.36	−0.60
	[-0.02, 0.64]	[-0.13, 0.91]	[-0.11, 0.58]	[-0.12, 0.57]	[0.43, 1.13]	[-0.38, 1.51]	[-0.13, 0.81]	[-0.78, 0.13]
D	0.43	0.74	0.95	1.32	0.81	0.63	0.26	−0.76
	[-0.24, 0.98]	[-0.52, 1.41]	[-0.81, 2.27]	[-1.02, 1.77]	[0.23, 1.68]	[-0.25, 1.48]	[-0.03, 0.70]	[-0.94, -0.11]
B	−0.29	−0.45	−0.64	−0.87	0.08	−0.53	−1.27	−2.57
	[-0.74, 0.15]	[-1.21, 0.36]	[-1.73, 0.57]	[-2.20, 0.53]	[-0.12, 0.30]	[-1.18, 0.19]	[-3.29, 0.83]	[-8.14, 1.81]

Note: A: Baseline, D: Deficit, B: Balanced Budget. Median multipliers and 68% HPDI in brackets.

Figure 1.12: Government Spending Shock: Deficit

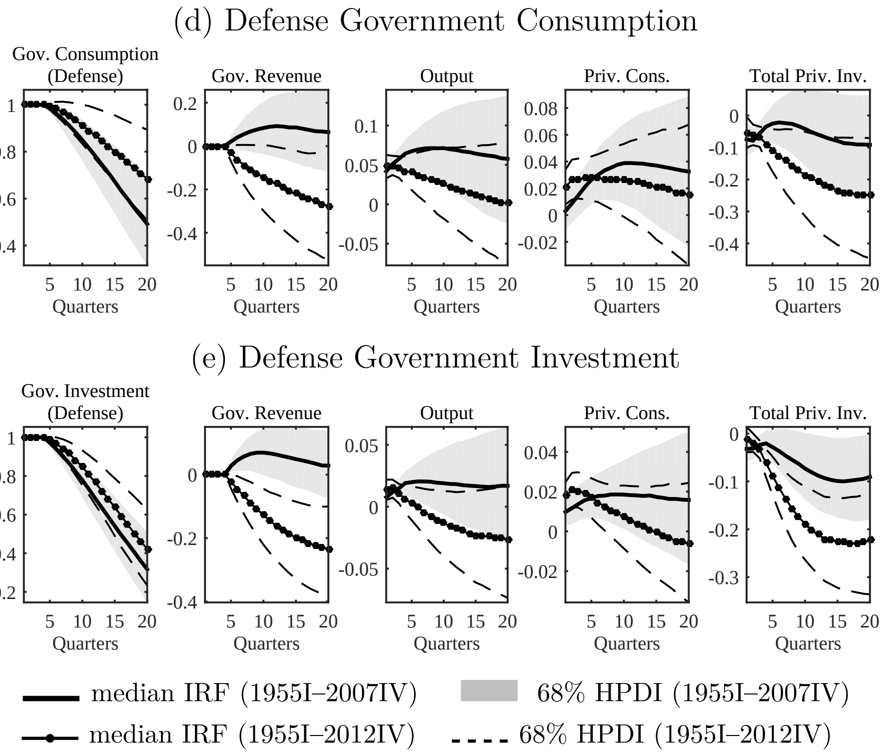


Figure 1.13: Government Spending Shock: Balanced Budget

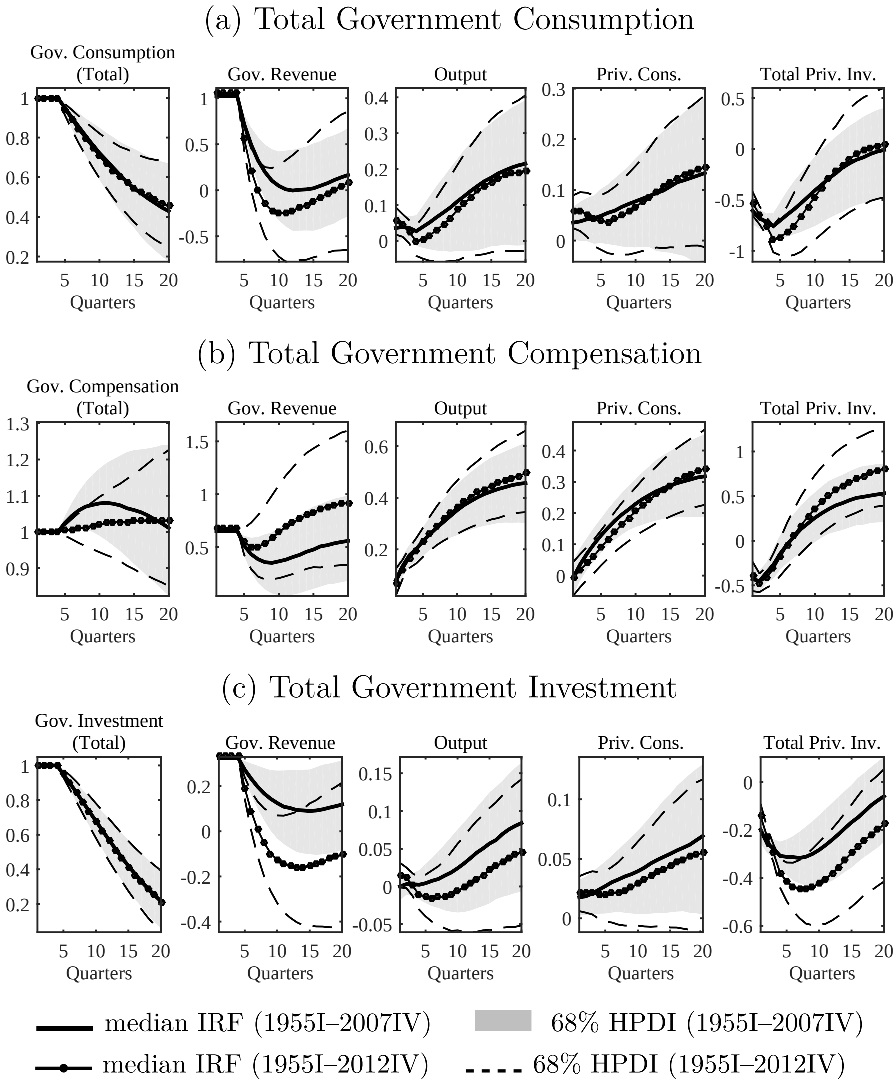
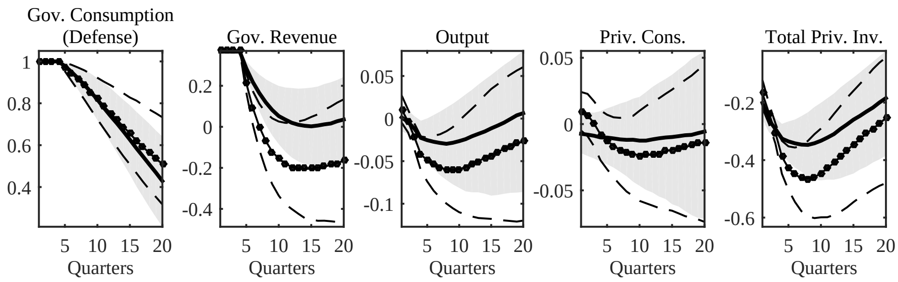
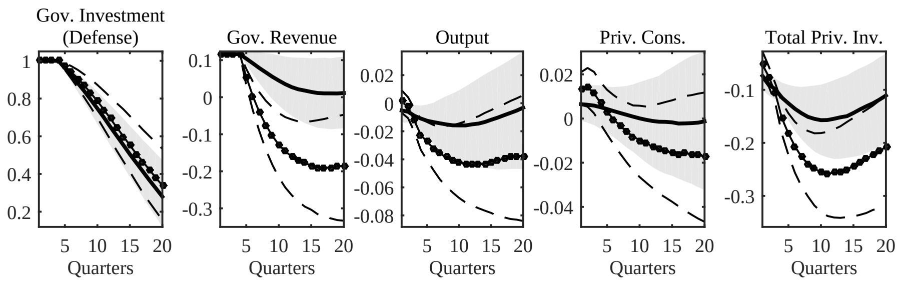


Figure 1.14: Government Spending Shock: Balanced Budget

(d) Defense Government Consumption



(e) Defense Government Investment



median IRF (1955I–2007IV) 68% HPDI (1955I–2007IV)
median IRF (1955I–2012IV) 68% HPDI (1955I–2012IV)

The inspection of Table 1.3 reveals that the multiplier associated to a shock to total government consumption is the same as in the baseline experiment and in the deficit financed case. This comes as no surprise as the comparison of Panel (a) of Figures 1.5 and 1.11 show that the response of government spending and revenues are extremely similar, leading to almost identical dynamics for the aggregates (output, private consumption and private investment). This finding is actually reminiscent of Mountford and Uhlig (2009) who also find it for total government expenditures. However, the similarities stop here. Indeed as soon as deficit financed total government investment of labor compensation are considered, the multipliers —especially the impact multipliers— differ from the baseline experiment. The multiplier is larger for investment, smaller for government compensation. Panel (c) of Figures 1.5 and 1.11 reveal that in the baseline experiment the shock to total government investment requires an increase in government revenues which crowd out private investment and limits the response of output. This is obviously not the case when the shock is deficit-financed as government revenues do not adjust. Results are qualitatively similar for defense spending such that the multipliers associated to both defense spending are larger —it doubles in the case of defense investment.

Table 1.3 also reveals that the differences between the pre-crisis and crisis samples are attenuated in the case of deficit-financed fiscal policy for all of the shocks, with an exception of the government investment shock. However, the output multipliers for both samples are only statistically significant for the government consumption and compensation shocks, and not for defense expenditure shocks. For government investment shocks, the output multipliers for the deficit-financed fiscal policy in the pre-crisis period are statistically positive and increasing over the horizon, but statistically insignificant throughout the crisis period. In case of a shock to total government consumption, the impact multiplier increased from 0.87 to 1 between the pre-crisis and the crisis sample — a 15% increase. In the deficit finance experiment, the corresponding multiplier increases from 0.84 to 0.91 —a 8% increase, about half of what obtained in the previous experiment. These findings are reversed in the government compensation case, the multiplier is higher in the crisis sample in the deficit financed case. A candidate explanation for the smaller differences across the sample can be found in the absence of adjustment of government revenues. Indeed, if the lack of adjustment of government revenue is accompanied/achieved by the absence of reaction of distorting taxation, this then does not add to the distortions induced by tighter financial conditions and therefore limits the distinction between the two samples.

When we impose the restriction that the tax revenue must be adjusted to guarantee a balanced budget in the year that follows the shock, the fiscal multipliers are statistically insignificant (with a notable exception of government compensation shock).

1.5 The role of Financial Conditions

This section investigates further the effects of the 2007-2009 financial crisis for the transmission of government shocks by studying a version of our VAR controlling for financial conditions. Fernández-Villaverde (2010), Canzoneri, Collard, Dellas, and Diba (Forthcoming), among others, have shown in general equilibrium models that financial conditions affect the transmission of fiscal policy and suggest that they should be controlled for in order to properly recover multipliers. As a way to investigate this issue, we first simply extend our set of variables to the National Financial Conditions Index (NFCI) which is a measure of risk, liquidity and leverage in money markets and debt and equity markets as well as in the traditional and shadow banking systems.[26] In that case, due to availability of the NFCI variable, the sample is restricted to the post 1973 period.

As shown in Canzoneri, Collard, Dellas, and Diba (Forthcoming), financial conditions ought to have non-linear implications for the propagation of government shocks and may induce some form of state dependence. To capture these non-linearities we also estimate a non-linear version of the VAR in which the lagged variables are considered in interaction with financial conditions. More precisely,

[26] Positive values indicate financial conditions that are tighter than average, while negative values indicate financial conditions that are looser than average.

let us define $X_t \equiv (Y_t, \varphi_t)$, where Y_t collects all the variables of our linear VAR (see Section 1.2.1) and φ_t is the financial condition variable, NFCI. Our non-linear VAR takes the form

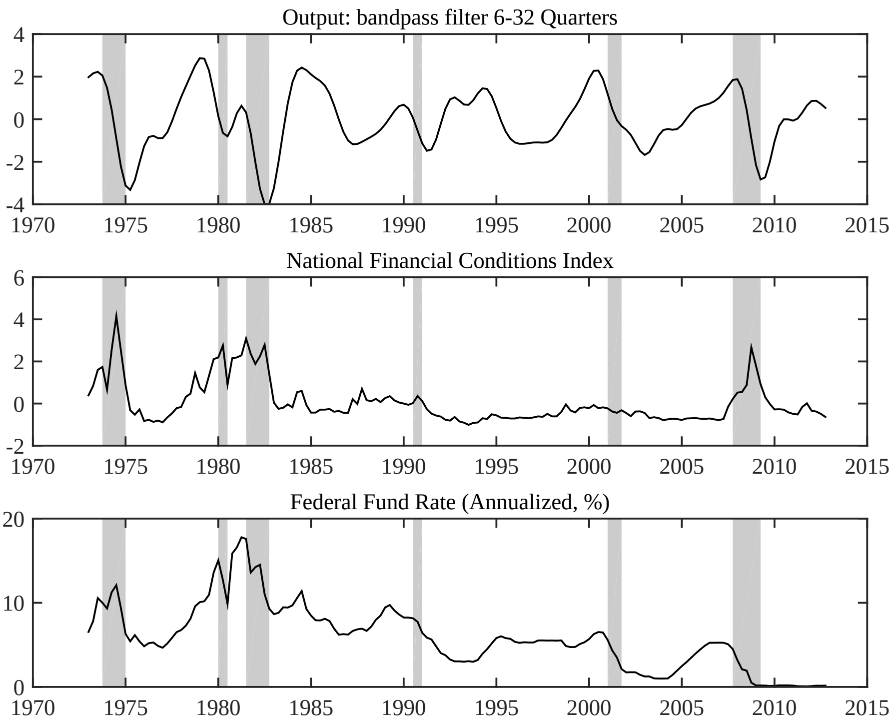
$$X_t = \sum_{i=1}^{p} A_i X_{t-i} + \sum_{i=1}^{p} B_i\, z_{t-i} \times X_{t-i} + u_t \tag{1.4}$$

where $z_t = \exp(\varphi_t)/(1+\exp(\varphi_t))$ guarantees that the distortion lies between 0 and 1. Our specification departs from that proposed by Auerbach and Gorodnichenko (2012), who consider a Smooth-Threshold VAR, in several dimensions. First, the model is not intended to recover the dynamics in different regimes characterizing the business cycle, but rather to compute the interactions between financial conditions and fiscal policy. We therefore do not model the transition probability between regimes. This permits to consider the simpler form of non-linearity in (1.4). Second, because the model is not to be interpreted as a regime switching model, there is no need to model state dependent covariance matrices. Third —and this is an implication of the last two observations— the non-linearity is found in the propagation of shocks only. Finally, contrary to Auerbach and Gorodnichenko (2012), we do not consider the interaction variable —the equivalent to their switching variable[27]— as exogenous, but rather explicitly model its dynamics (last equation in the non-linear VAR, Equation (1.4)). An implication of the assumed endogeneity of financial conditions is that the computation of impulse response functions is fundamentally non-linear. We therefore adopt the generalized impulse response approach proposed by Koop, Pesaran, and Potter (1996) to compute the dynamics of aggregates after a shock.

We consider three situations, which all correspond to specific conditions on financial markets. We are not interested in recovering multipliers in recessions versus expansions, but rather aim at characterizing the way financial conditions shape the multipliers. We start by investigating the response of the economy to a government shock, and the level of the associated multiplier, when the economy

[27]Auerbach and Gorodnichenko (2012) consider, as switching variable, a backward-forward moving average of output growth and compute their Impulse response function without taking into account that, along the dynamics, the switching variable may vary.

Figure 1.15: Data: Financial Conditions and Interest Rate



Note: The shaded areas correspond to recessions as identified by the NBER.

faces loose financial stress while being in a recession. This is achieved by using, as initial condition to build the generalized impulse responses, the state of the economy in the third quarter of 2001. We then compare the so-obtained set of IRFs to what obtains when the economy is started in the last quarter of 2008, where the financial index indicates that the economy is under high financial stress.[28] Note however that the economy actually faces two important frictions that ought to affect the multiplier: tight financial conditions and the zero lower bound (ZLB). Therefore, in order to tell apart the effects of financial conditions and those of the ZLB, we also report results when the economy is started in the third quarter of 1981, where the economy faced a recession of a similar size as in 2008 and very similar index of financial conditions, but was clearly not at the ZLB (See Figure 1.15).

Tables 1.4 and 1.5 report the median of the discounted fiscal multipliers associated with consumption and investment expenditures[29] and Figure 1.16 the associated impulse responses. As suggested by the results of Section 1.3, the multipliers obtained over the period 1973I-2012IV in the linear VAR are larger than those in the full sample. For example, the impact multipliers of total government consumption and investment are, respectively, 1.77 and 2.18 over the post 1973 period, versus 1.00 and 0.90 in the full sample. The results for the non-linear VAR are also in line with previous results by Afonso, Baxa, and Slavík (2011) and Ferraresi, Roventini, and Fagiolo (2014) in threshold VARs. Under loose financial conditions, the impact multiplier is close to that obtained in the linear VAR, although slightly lower.[30] Indeed, as can be seen from Figure 1.16 the response of most variables are extremely close to those obtained in the linear VAR when financial conditions are loose (dashed line). This is true both for total government consumption and investment expenditures. Note that the difference is more pronounced when defense spending are considered, with a multiplier in loose

[28]We chose these two episodes such that the size of the drop in output from peak to trough is comparable.

[29]We omit government compensation as, in the non-linear setting, the impulse responses are explosive.

[30]This last finding reflects the fact that, on average, financial conditions are loose.

Table 1.4: Discounted Multipliers: Financial Conditions

	Impact	1 Year	2 Years	5 Years
	Total Government Consumption			
Linear	1.77	1.12	0.55	-0.25
	[0.95, 2.57]	[0.77, 1.53]	[0.43, 0.68]	[-2.00,1.59]
Loose	1.72	1.20	0.64	-0.25
	[1.23, 2.15]	[0.81, 1.64]	[0.49, 0.77]	[-2.32, 2.06]
Tight	2.12	1.11	0.23	-0.35
	[1.17, 3.23]	[0.84, 1.55]	[-0.63, 1.10]	[-2.16, 1.89]
Tight-ZLB	2.99	1.00	-0.31	-1.37
	[2.49, 3.36]	[0.74, 1.41]	[-2.33, 1.89]	[-3.28, 0.54]
	Total Government Investment			
Linear	2.18	1.71	0.99	-0.74
	[1.38, 2.87]	[0.95, 2.57]	[0.53, 1.40]	[-1.93, 1.24]
Loose	2.37	1.91	0.77	-1.92
	[1.77, 3.11]	[1.44, 2.47]	[0.30, 1.17]	[-3.98, 0.45]
Tight	2.97	2.81	2.02	-0.13
	[2.20, 3.47]	[2.28, 3.53]	[1.40, 2.71]	[-2.32, 2.06]
Tight-ZLB	3.70	2.46	0.57	-2.72
	[3.15, 4.40]	[2.01, 3.04]	[0.08, 1.15]	[-12.11, 9.22]

<u>Note:</u> Median multipliers and in brackets 68% HPDI

Table 1.5: Discounted Multipliers (Defense): Financial Conditions

	Impact	1 Year	2 Years	5 Years
	Defense Government Consumption			
Linear	1.96	1.38	0.62	-0.97
	[1.14, 2.81]	[0.54, 2.15]	[-0.49, 1.67]	[-1.94, 0.04]
Loose	1.38	1.80	1.85	0.98
	[1.21, 1.44]	[1.38, 2.27]	[1.04, 2.78]	[-0.56, 2.63]
Tight	2.29	1.22	0.12	-1.22
	[0.92, 3.55]	[1.11, 1.34]	[-0.32, 0.64]	[-3.08, 0.34]
Tight-ZLB	2.85	1.35	-0.05	-1.77
	[1.57, 4.24]	[0.54, 2.15]	[-1.12, 1.00]	[-3.78, 0.25]
	Defense Government Investment			
Linear	2.51	1.80	0.88	-1.50
	[1.70, 3.32]	[0.62, 3.01]	[-0.17, 1.69]	[-3.28, 0.54]
Loose	1.59	2.86	3.26	1.41
	[1.27, 1.91]	[2.35, 3.36]	[1.94, 4.69]	[-1.26, 3.78]
Tight	4.49	2.77	1.02	-1.61
	[4.03, 5.10]	[2.21, 3.24]	[0.40, 1.65]	[-3.66, 0.13]
Tight-ZLB	4.66	2.60	0.77	-1.97
	[3.99, 5.24]	[2.09, 3.13]	[0.32, 1.19]	[-4.19, 0.17]

Note: Median multipliers and in brackets 68% HPDI financial conditions way below that observed in the linear VAR.

The figures change quite dramatically when financial conditions are tight, as was the case during the 1981 recession. The impact multiplier then increases and is well above that obtained in the linear VAR. For instance, a shock to total (and defense) consumption expenditures leads to a multiplier above 2 on impact. Similarly, the impact multipliers associated with investment spending are above 3. In both cases they decline quite quickly and become negative within 5 years. The results are consistent with results obtained by Canzoneri, Collard, Dellas, and Diba (Forthcoming) in a DSGE model featuring financial frictions à la Curdia and Woodford (2010).[31] When the economy reaches the zero lower bound, as was the case during the 2007-2009 recession, the impact multiplier is even stronger, reaching 3 in the case of a government consumption shock and almost 4 in the case of a government investment shock. This result is consistent with Christiano, Eichenbaum, and Rebelo (2011) and others who showed when the nominal interest rate is stuck at zero the rise in expected inflation that follows the fiscal stimulus drives down the real interest rate and therefore stimulates private spending and hence output. But it also rises the marginal cost and triggers another increase in expected inflation that feeds the decrease in the real interest rate. Multipliers can then be quite large.[32]

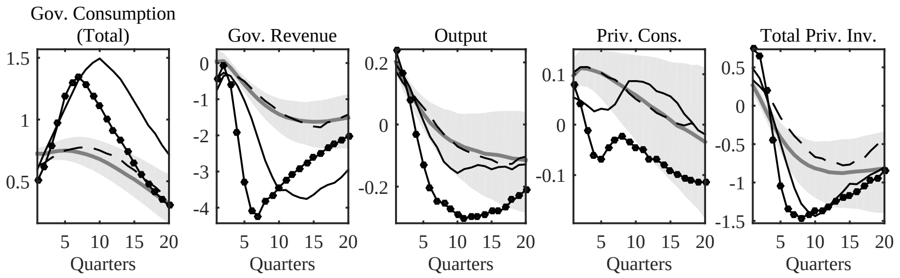
It is important to note that we only consider recessions episodes in our experiments, and our results suggest that the multiplier is actually sensitive to the tightness of the financial conditions. The financial tightness accounts for a substantial part of the rise in the multiplier. For instance, moving from loose to

[31] Their model features a countercyclical financial accelerator embodied in the spread between the borrowing rate and the lending rate. The countercyclicality is the result of the countercyclicality of bank intermediation costs In a recession the cost of bank intermediation increases and so does the spread, therefore worsening financial conditions. An increase in government spending stimulates the economy which reduces the spread and lowers the borrowing rate which stimulates consumption and in turn output, leading to a further decrease in the spread and feeding the boom. The same mechanism works symmetrically during booms, but the initial expansion is limited due to the non-linearities at work in the model.

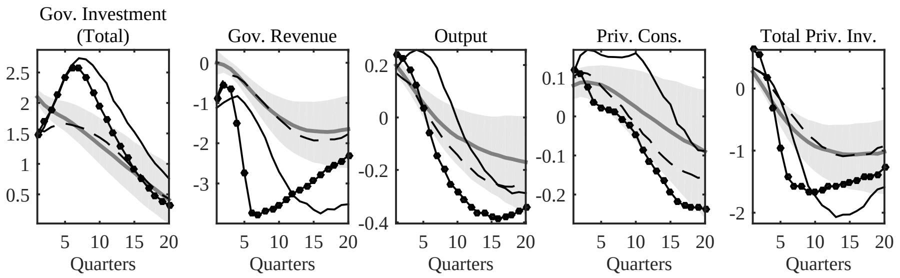
[32] Note however that the size of the multiplier is also determined by other factors that can limit its increase. See Cogan, Cwik, Taylor, and Wieland (2010).

Figure 1.16: Government Spending Shock: Non linear VAR

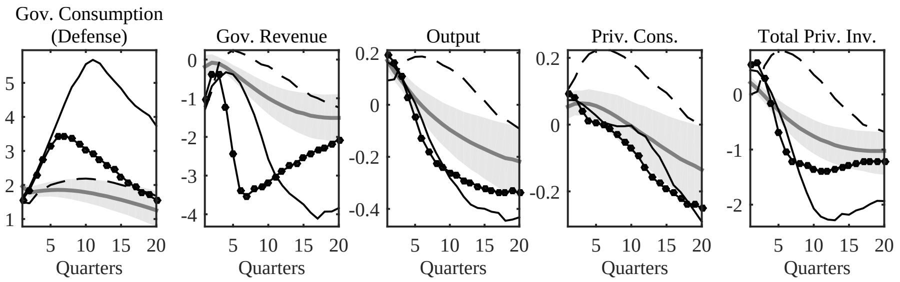
(a) Total Government Consumption



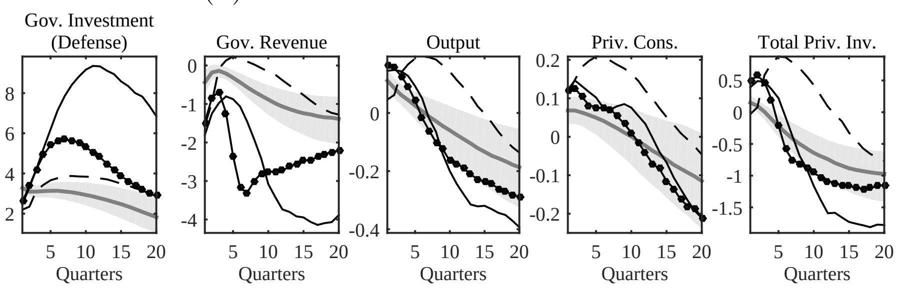
(b) Total Government Investment



(c) Defense Government Consumption



(d) Defense Government Investment



median IRF, Linear VAR 68% HPDI (Linear VAR), median IRF, Non-Linear VAR, tight financial conditions, median IRF, Non-Linear VAR, tight financial conditions, ZLB. median IRF, Non-Linear VAR, loose financial conditions.

tight financial conditions leads to an increase in the multiplier associated with a government consumption (resp. investment) shock of 23% —from 1.72 to 2.12— (resp. 25%, from 2.37 to 2.97). But the ZLB leads (holding financial tightness constant) to a further 41% increase in the impact multiplier associated to the government consumption shock (25% in the case of an investment spending shock). These results are in line with the theoretical work of Eggertsson (2010), Christiano, Eichenbaum, and Rebelo (2011) or Braun and Körber (2014) which shows that the fiscal multiplier increases dramatically in a liquidity trap. It is therefore the interaction between monetary policy and financial constraints that explains the bulk of the increase in the multiplier.

1.6 Concluding Remarks

The aim of this paper was twofold. First it aimed at comparing of dynamics, both in terms of impulse responses and multipliers, of the main macroeconomic aggregates following a shock affecting one of the main components of government spending –*i.e.* government consumption, government investment or labor compensation– in a unified framework. Our results indicate that government consumption shocks— either affecting total expenditures or defense expenditures only— lead to a mild positive response of both consumption and output, but exerts a crowding out effect on private investment. Accordingly, the associated short-run multipliers are below unity both for output and consumption. The crowding out effect on private investment is stronger when the shock affects productive expenditures –*i.e.* government investment– and the short-run multiplier is, not surprisingly, lower than in the case of a government consumption shock. But, in line with the theory, a shock to government investment generates, through the accumulation of public capital, a positive wealth effect that makes the multipliers larger in the longer run. These results remain similar whether we consider total government expenditures or those pertaining to defense purposes only. Multipliers are larger (about 1.5) when the shock affects labor compensation, as it is found not to create crowding out effect on the good market. Interestingly, fiscal spending shocks (notably government consumption and compensation shocks) have a larger impact when the sample includes the “Great Recession” episode. One potential explanation for this result lies in the fact that the cyclical component of government expenditures become more countercyclical as we include the financial crisis in the sample.

We therefore investigate –and this is the second aim of this paper– the possibility that, as suggested by several recent theoretical papers (see e.g. Fernández-Villaverde (2010) or Canzoneri, Collard, Dellas, and Diba (Forthcoming)), the presence of stronger financial frictions has had an impact on the transmission of fiscal shocks, therefore amplifying their effect on aggregate variables. The aforementioned theoretical work however highlighted that such an effect transit through non-linear mechanisms. Accordingly, we rely on a non-linear VAR model allowing us to investigate the role of the interaction between financial conditions and macroeconomic dynamics and we indeed find evidence in favor of a significant role of financial frictions. More specifically, our results indicate that multipliers are larger when the financial conditions are tight. In particular, a deterioration of financial conditions leads to an increase in the multiplier associated with a government consumption (resp. investment) shock of about 25% (resp. 25%). Using the same methodology, we also show that when the economy hits the zero lower bound, the multiplier increases further by about 40% in the case of a government consumption shock and 25% in the case of a public investment shock –hence confirming previous work by Eggertsson (2010), Christiano, Eichenbaum, and Rebelo (2011) or Braun and Körber (2014). We conclude this interaction between financial frictions and monetary policy accounts for the increase in the multiplier during the last financial crisis.

APPENDIX

1.A Estimation

1.A.1 The Minnesota Prior

The Minnesota prior incorporates the belief that the endogenous variables in the VAR follow either a random walk or a stationary AR(1) process. Hence, for a VAR of the form

$$Y_t = C + \sum_{\tau=1}^{p} A_\tau Y_{t-\tau} + u_t \tag{1.A.1}$$

where Y_t is $(n \times 1)$, the Minnesota prior imposes the following structure on the belief

$$Y_t = \begin{pmatrix} 0 \\ \vdots \\ 0 \end{pmatrix} + \begin{pmatrix} \rho_{11}^0 & 0 & \cdots & 0 \\ 0 & \rho_{22}^0 & \cdots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \cdots & \rho_{kk}^0 \end{pmatrix} Y_{t-1} + \sum_{\tau=2}^{p} \begin{pmatrix} 0 & \cdots & 0 \\ \vdots & \ddots & \vdots \\ 0 & \cdots & 0 \end{pmatrix} Y_{t-\tau} + u_t$$

where $\rho_{ii}^0 = 1$ in the case of a random walk prior, $\rho_{ii}^0 = \overline{\rho} \in (-1, 1)$ in the case of the AR(1) prior. Then the prior distribution of the vector θ of parameters of the VAR is Gaussian with mean θ_0 and covariance matrix Ω_0 where

$$\theta_0 = \begin{pmatrix} \theta_{01} \\ \vdots \\ \theta_{0k} \end{pmatrix}$$

with

$$\theta_{0i} = (\underbrace{0, \cdots, 0}_{\substack{c_j \\ 1 \text{ Coef.}}}, \underbrace{0, \cdots, \rho_i^0, \cdots, 0}_{\substack{A_{1i} \\ n \text{ Coef.}}}, \underbrace{0, \cdots, 0}_{\substack{A_{1j} \\ (p-1)n \text{ Coef.}}})'$$

where θ_{0i} collects the coefficients of the equation describing the dynamics of the endogenous variable Y_{it}, p is the number of lags and n the number of endogenous variables. The covariance matrix Ω_0 is a diagonal matrix with elements $\lambda_0^2\sigma_i^2$ for the coefficients pertaining to the exogenous variables (the deterministic part in 1.A.1), and

$$\psi_{ij,\tau} = \begin{cases} \left(\frac{\lambda_1}{\tau^\eta}\right)^2 & \text{for element } A_{i,\ell j},\ \ell = j \\ \left(\frac{\sigma_i\lambda_1\lambda_2}{\sigma_j\tau^\eta}\right)^2 & \text{for element } A_{i,\ell j},\ \ell \neq j \end{cases}$$

for the coefficients governing the dynamics of variables. The role of the various coefficients entering the priors is clear. The coefficient λ_0 controls for the tightness of the prior on exogenous variables ($\lambda_0 \to 0$ implies that the coefficient is set exactly at its prior mean, 0). Likewise λ_1 controls for the tightness of the prior of the coefficient controlling the response of an endogenous variable to its own past. λ_2 controls the tightness of the prior of an endogenous variable to the past of one of the other endogenous variables. In particular when $\lambda_2 = 1$ no distinction is made between the response to its own past or to the past of the other endogenous variables (once the relative volatilities are controlled for). Recalling that p is the number of lags, the parameter η controls the degree of response of the variable to further past. The larger η, the faster the effects of the past vanishes (as the coefficients shrink to 0 at a faster pace for larger values of η). The Ω_0 has therefore the form

$$\Omega_0 = \begin{pmatrix} \Omega_{01} & \cdots & 0 \\ \vdots & \ddots & \vdots \\ 0 & \cdots & \Omega_{0k} \end{pmatrix}$$

where

$$\Omega_{0i} = \begin{pmatrix} \lambda_0^2\sigma_i^2 & 0 & & & \\ 0 & \Psi_{i1} & 0 & \cdots & 0 \\ 0 & 0 & \Psi_{i2} & \cdots & 0 \\ 0 & 0 & \vdots & \ddots & \vdots \\ 0 & 0 & 0 & \cdots & \Psi_{ik} \end{pmatrix}$$

where

$$\Psi_{i\tau} = \begin{pmatrix} \psi_{i1,\tau} & 0 & \cdots & 0 \\ 0 & \psi_{i2,\tau} & \cdots & 0 \\ \vdots & \ddots & \ddots & \vdots \\ 0 & 0 & \cdots & \psi_{in,\tau} \end{pmatrix}$$

In this application, we follow Canova (2007) and set $\lambda_0 = 10^5$, $\lambda_1 = 0.2$, $\lambda_2 = 0.5$ and $\lambda_3 = 2$. Sensitivity analysis revealed the robustness of our findings to changes in these parameters.

Under this prior, θ is distributed as $\mathcal{N}(\theta_0, \Omega_0)$ while the conjugate prior for the covariance matrix of the VAR, Σ is an inverse Wishart (IW) distribution with prior scale S and prior degrees of freedom, κ.

1.A.2 The Gibbs Sampler

Using the prior described in the previous section, an algorithm for the Gibbs sampler works as follows:

1. Set an initial value for Σ. In practice we used the OLS estimate.

2. Sample the coefficients of the VAR from the conditional posterior distribution $F_\theta(\theta|\Sigma, Y_t) = \mathcal{N}(\theta^\star, \Omega^\star)$ where

$$\theta^\star = (\Omega_0^{-1} + \Sigma^{-1} \otimes X'X)^{-1}(\Omega_0^{-1}\theta_0 + \Sigma^{-1} \otimes X'X\widehat{\theta})$$
$$\Omega^\star = (\Omega_0^{-1} + \Sigma^{-1} \otimes X'X)^{-1}$$

where X is a $(T, n \times (p+1))$ matrix gathering all regressors (lagged variables and constant), Γ denotes the current draw of the covariance matrix of the VAR, $\widehat{\theta}$ denotes the OLS estimates of the (vectorized) coefficients of the VAR,

θ_0 is the prior mean of the VAR coefficients, and Ω_0 the associated prior of the covariance matrix. A new draw of the coefficients is then obtained as

$$\widetilde{\theta} = \theta^{\star} + \widetilde{s}\,\Omega^{\star 1/2}$$

where $\widetilde{s} \rightsquigarrow \mathcal{N}(0, I)$.

3. Sample Σ from its conditional posterior distribution $F_{\Sigma}(\Sigma | j, Y_t) = \mathrm{IW}(\overline{\Sigma}, T + \kappa)$ where

$$\overline{\Sigma} = S + (Y - X\widetilde{\theta})'(Y - X\widetilde{\theta})$$

where $\widetilde{\theta}$ is the draw of the VAR coefficients obtained in the previous step.[33]

These steps are repeated N times to obtain draws from the posterior distribution $\{\widetilde{\theta}_s, \widetilde{\Sigma}_s\}_{s=1}^{N}$, which are then used to compute the confidence bands for the impulse functions.

1.A.3 The Penalty Function

Recall that the matrix Q is obtained by minimizing a penalty function that penalizes rotations of the Cholesky impulse matrix that do not satisfy the set of identifying restrictions imposed by the econometrician and solves the problem

$$\begin{aligned} &\min_{\widetilde{Q}} \mathcal{P}(\widetilde{Q}) \\ &s.t.\ \widetilde{Q}\widetilde{Q}' = I \end{aligned} \tag{1.A.2}$$

where the penalty function $\mathcal{P}$ is borrowed from Uhlig (2005) and Mountford and Uhlig (2009):

$$\mathcal{P}(Q) = \sum_{j \in J_+} \sum_{\tau=0}^{m-1} f\left(-\frac{x^j_{s,\tau}}{\sigma_j}\right) + \sum_{j \in J_-} \sum_{\tau=0}^{m-1} f\left(\frac{x^j_{s,\tau}}{\sigma_j}\right)$$

where J_+ (resp. J_-) denotes the set of variables for which the identification imposes a positive (resp. negative) response of the variable to the shock for the first m

[33] As explained in Uhlig (2005), drawing from an inverse Wishart distribution $\mathrm{IW}(S, \kappa)$ can be simply achieved by drawing a matrix $Z(n \times \kappa)$ from a $\mathcal{N}(0, S^{-1})$ and then computing $\widetilde{\Sigma} = \left(\sum_{i=1}^{n} Z_i Z_i'\right)^{-1}$.

periods. Note that the impulse response function of each variable is normalized by its standard deviation as a way to avoid scale effects problem. The function $f(\cdot)$ takes the form $f(x) = \lambda x$ if $x \geqslant 0$ with $\lambda > 1$ and $f(x) = 0$ if $x < 0$. The choice of λ is not innocuous. If λ is too small, the penalty is not stringent enough, if its too large numerical problems may affect the minimization. We follow Uhlig (2005) and use $\lambda = 100$.[34]

From a practical point of view, this procedure is implemented sequentially. The business cycle shock is identified first, which amounts to select a vector Q_1 that solves problem (1.A.2) with the sole constraint $Q_1'Q_1 = 1$. The second shock is then identified, which amounts to solve a second problem of the type of (1.A.2), imposing the constraints $Q_2'Q_2 = 1$ and $Q_2'Q_1 = 0$. This extends to the other shocks. From a numerical point of view the minimization is performed using the constrained minimization procedure as implemented by Matlab (`fmincon`).

1.A.4 Computation of Generalized Impulse Response Functions

The computation of Impulse Response Functions (IRF) is conducted in the lines of Koop, Pesaran, and Potter (1996). In case of an arbitrary shock of magnitude Δ, given state variables at time 0, an IRF for variable x at horizon h is defined as:

$$I_x(h, \Delta, 0) = E[x_{t+h}|\Delta; \mathcal{I}_0] - E_0[x_{t+h}|\mathcal{I}_0]$$

where $\mathcal{I}_0$ is the information set. Conditional expectations, involved in IRF computations, are calculated using Monte-Carlo integration. Then IRF are obtained as follows:

Step 1: We set the horizon H of IRF. The economy is placed at a particular point of the sample. We draw N random vector u_h, $h = 1, \dots, H$, from the distribution of the fundamental shocks of the nonlinear VAR.

Step 2: We simulate N time series of length (H) for the vector of variables using the nonlinear VAR (1.4). These time series are denoted $x_h^n(A_0, z_h)$ for $n = 1, \dots, N$

[34] We also experimented with alternative values for λ and found that the results were left unaffected.

and $h = 1, \ldots, H$.

Step 3: We replicate the computation of step 2, where the structural shock under study is perturbed by 1 standard deviation. The so–obtained time series, which correspond the shocked time series, are denoted $x_h^n(A_0, \tilde{z}_h(\Delta))$ for $n = 1, \ldots, N$ and $h = 1, \ldots, H$.

Step 4: We form the averages for each simulated data:

$$\begin{aligned}
\bar{x}_{h,0}^N &= \frac{1}{N}\sum_{n=1}^{N} x_n^h(A_0, z_h) \quad , h = 0, \ldots, H \\
\bar{x}_{h,\Delta,0}^N &= \frac{1}{N}\sum_{n=1}^{N} x_n^h(A_0, \tilde{z}_h(\Delta)) \quad , h = 0, \ldots, H
\end{aligned} \tag{1.A.3}$$

Step 5: We compute the IRF as the difference between the two averages :

$$I_x^N(h, \Delta, 0) = \bar{x}_{h,\delta,0}^N - \bar{x}_{h,0}^N \quad h = 0, \ldots, H$$

For N large, we have:

$$\lim_{N\to\infty} I_x^N(h, \delta, 0) = I_x(h, \Delta, 0) \quad h = 0, \ldots, H$$

1.B Description of the Data

All variables are expressed in real terms per capita by dividing them by the implicit price deflator of GDP, (Line 1 from NIPA Table 1.1.9), and population (Line 40from NIPA Table 2.1). The other variables are then constructed using their relative share in GDP. Consumption and investment shares are obtained relying on the NIPA Table 1.1.5.

- Gross Domestic Product: Line 1
- Non Durable Consumption: Line 5
- Services Consumption: Line 6
- Total Consumption: (Line 5+Line 6)
- Total Investment (Gross private domestic investment + durable consumption): (Line 7+Line 4)
- Residential Investment: Line 13
- Non Residential Investment: Line 9

Variables pertaining to government spending and revenues are built in the same way. The shares are obtained by dividing the various indicators (as obtained from NIPA Tables 3.1, 3.9.5 and 3.10.5)

- Net Taxes (Current receipts-Transfer payments-Interest payments): Line 1-Line 19-Line 24 of Table 3.1
- Total Government Consumption: Line 2 of Table 3.9.5
- Total Government Investment: Line 3 of Table 3.9.5
- National Defense Government Consumption: Line 18 of Table 3.9.5
- National Defense Investment: Line 19 of Table 3.9.5
- Compensation of General Government Employees: Line 4 of Table 3.10.5

- Aggregate price level corresponds to the Log of the implicit GDP deflator (as obtained from FRED, `GDPDEF`)

- Interest rate corresponds to the 3-Month treasury bill: Secondary Market (as obtained from FRED, `TB3MS`). We also used the Effective Federal Fund rate (as obtained from FRED, `FEDFUNDS`)

- The commodity price is measured by the Producer Price Index: Crude Materials for Further Processing (as obtained from FRED, `PPICRM`)

- Adjusted reserves are measured by the adjusted monetary base (as obtained from FRED, `ADJRESSL`)

- To measure financial conditions, we use the National Financial Conditions Index (as obtained from FRED, `NFCI`) which is a measure of risk, liquidity and leverage in money markets and debt and equity markets as well as in the traditional and "shadow" banking systems. Positive values indicate financial conditions that are tighter than average, while negative values indicate financial conditions that are looser than average.

Note that arithmetic averages were used to convert monthly figures to quarterly figures.

Chapter 2

Fiscal Policy Rule: Does Implementation Matter?

2.1 Introduction

The recent financial crisis has revived interest in activist fiscal policy as a way to stabilization the business cycle. Governments have responded to the “Great Recession” relying on rather aggressive stimulus packages as a way to stimulate demand with lower taxes and higher government spending. However, the resulting public debt buildups have raised concerns about the financing of these measures, which in turned fueled the debate on the potency of fiscal instruments. There thus seems to exist a trade-off between using fiscal instruments as a way to stabilize the business cycle and fiscal discipline, as manifested by the posted willingness of governments to keep public debt under control. This trade-off ought to limit the effectiveness of governments in stabilizing the business cycle. The objective of this paper is to investigate this issue, in particular asking the question of the implementation of fiscal rules.

Unlike monetary policy, where the Taylor (1993) rule is commonly viewed as a fairly accurate representation of most Central Banks’ behavior, there is no widely accepted fiscal rule. Taylor (1996, 2000), in the spirit of the monetary policy rule, reported empirical evidence supporting the view that a fiscal rule relating a measure of fiscal stances to a measure of the output gap exists for the United States. Recessions are associated with reductions in fiscal stances indicating that fiscal policy is countercyclical. Bohn (1998) reports empirical evidence in favor of a positive relationship between the government surplus to GDP ratio (a measure of fiscal stances) and the government debt to GDP ratio –indicating that government deficits (surplus) are used to stabilize the evolution of debt. Favero and Monacelli (2005) showed that the fiscal policy regime in the United States can be adequately described in terms of a systematic simple rule in which both the debt and output gap stabilization motives are present. The present paper proposes an integrated approach in which the government deficit (or total tax revenues) respond both to a measure of the output gap, as in Taylor (1996, 2000), and also to the level of public debt, as in Bohn (1998). The paper therefore does not take a stand *a priori* on which of the two sides of the aforementioned trade-off matters the most –stabilization or fiscal discipline– instead it lets the data speak. Another point of departure of the present paper from the previous literature is that, in the latter, the relationship between fiscal stances and the other measure was contrived to a framework that ignored the potential feedback effects they generate.[1] On the contrary, the present paper estimates the fiscal rule in a full-fledged general equilibrium model, therefore taking into account all potential interactions between fiscal policy and the macroeconomy. In that sense, the paper belongs to the literature that studies fiscal policy in dynamic stochastic general equilibrium (DSGE) models. In particular, it relates to the seminal paper by Leeper, Plante, and Traum (2010) which offered an analysis of the financing of government debt in the US and of the role of fiscal policy in shaping the business cycle. In their setting, fiscal policy consists of a set of rules –one for each fiscal policy instrument[2]– that respond both to a measure of the output gap and to

[1] Like the approach taken by Taylor (1993) these papers adopt a single equation estimation framework that ignores the potential feedback effects present in a general equilibrium model during estimation. For instance, any modification of fiscal stances exerts an effect on the level of output (or debt) through its effects on the behavior of the other agents in the economy, which in turn requires a modification of fiscal policy by the governmental authorities.

[2] Leeper, Plante, and Traum (2010) consider capital, labor, and consumption taxes, government

public debt. The present paper borrows from Leeper, Plante, and Traum (2010) in the sense that fiscal policy also responds to the output gap and public debt. It however departs from it in two important ways. First, while Leeper, Plante, and Traum (2010) consider a real model, the present paper models an economy featuring nominal rigidities, therefore allowing to explicitly take into account the interaction between fiscal and monetary policies, which ought to have significant implications both for financing of public debt and output stability. A second important point of departure from their analysis is found in the exact modeling of fiscal policy. Leeper, Plante, and Traum (2010) formulate a specific rule of each of the fiscal policy instrument they consider. An advantage of their approach is that it gives a lot of degrees of freedom to improve the fit of the model.[3] One drawback is that it does not separate the policy objective from the way it is implemented. In the present paper, fiscal policy is modeled as a single rule relating total fiscal stances to a measure of the output gap and public debt. In particular, given exogenous government spendings, this rule can be given a "deficit rule" interpretation. Hence, in the current model, the government has a primary deficit objective which aims at achieving output stabilization while maintaining public debt under control. It then adjusts the tax system to finance it. Which of the tax should be adjusted is *a priori* indeterminate in a positive context. Following Tinbergen's rule, only one instrument at a time is used to achieve this increase in tax revenues, holding all other tax rates (and the lump sum tax) constant.[4] This setup allows for a separation between the stabilization policy from its financing, and as such provides us with a better structured framework to understand these two aspects of fiscal policy. The question of the implementation is important as different tax instruments may lead to different outcomes both in terms of potency and efficiency.

The model builds upon the standard DSGE model à la Smets and Wouters

spending, and lump sum transfers.

[3]One may actually overturn this argument arguing that it does not lead to a parsimonious model.

[4]For example, to implement the rule by labor tax adjustment then only labor tax is allowed to vary and all the other ones are kept constant.

(2007) or Justiniano, Primiceri, and Tambalotti (2010)[5] extended to the presence of explicit fiscal stabilization policy. As already discussed, fiscal policy is modeled as a tax income rule which serves two main purposes: *(i)* to achieve output stability and *(ii)* to discipline the evolution of real debt and aid its sustainability. The motivation for this extension is grounded in the question addressed in this paper: the evaluation of the effectiveness of individual tax instruments (a lump sum tax or either a labor, a capital or a consumption tax), used to finance public debt, to stabilize the business cycle. The model is then estimated on US quarterly data for the period 1960Q1–2007Q4[6] using Bayesian maximum likelihood in the frequency domain as recently advocated by Christiano and Vigfusson (2003) and Sala (2012). An advantage of this approach is that it permits to focus explicitly on business cycle frequencies. The stabilization and fiscal discipline properties of the rule are then assessed by looking at the response of the main aggregates to the shocks hitting the economy, and by looking at their second order moments.[7] The potency of individual tax instruments is then assessed by comparing their performance in terms of reduction of output volatility and the elasticity of output to changes in each tax in face of the various shocks in the model.

The results indicate that the choice of the tax instrument used to balance the government budget constraint quantitatively affects the propagation of shocks. The most stabilizing tax, in terms of unconditional output volatility, is the lump sum tax. This comes as no surprise as, by not distorting any of the decisions of the agents, this tax does not create any additional incentive at the margin to vary hours worked or investment more than what the standard wealth and substitution effects would prescribe. However, such a tax is essentially absent from most tax systems which essentially rely on distortionary taxation. The labor tax is the

[5]The model therefore features nominal rigidities à la Calvo (1983) affecting both prices and nominal wages, an explicit monetary policy that takes the form of a Taylor rule, habit persistence, investment adjustment costs and endogenous utilization.

[6]This sample therefore excludes the recent financial crisis for which the model we consider is not suited.

[7]The analysis is therefore strictly positive, and the paper is silent about the normative aspects of fiscal policy.

most stabilizing tax, in terms of output volatility, followed by the consumption tax and the capital tax. However the differences are quantitatively small, suggesting that the implementation does not matter much for unconditional volatility. The same result holds for co-movements. These results indicate that as long as the government uses a deficit rule, the exact details of its implementation have very little quantitative consequences for the positive properties of the economy. This stands in contrast to models that specify a rule for each tax rate in the system (for example Leeper, Plante, and Traum (2010)).[8] Likewise the choice of the tax instrument does not affect much the contribution of each shock to output volatility. The main contributors to output volatility are the neutral technology and cost push shocks (both 16% on impact in the baseline model), the investment efficiency shock (27%) and the wage markup shock (22%), although for the latter the contribution becomes more sizable as the horizon increases (55% after 5 years). Furthermore, the results indicate that letting either the labor tax, the consumption tax, the capital tax or the lump-sum component of the tax adjust does not affect neither qualitatively nor quantitatively the contribution of each shock to the dynamics of output. In other words, the policymaker is not in a position to affect the contribution of each shock to the business cycle by simply varying the tax instrument she uses while using a simple deficit (or total tax revenue) rule. Does it mean that the choice of the tax is irrelevant? The answer is no. Differences are more clear-cut when the focus is shifted towards the response of the economy to individual shocks. For example, the wage markup shock affects directly the wage markups and the labor tax that are the main driver of the labor wedge –which has been found by Chari, Kehoe, and McGrattan (2007) to be key in shaping the business cycle– such that alternative tax instrument then have stronger implications on the dynamics than a technology shock. Furthermore, the choice of the tax affects the tax elasticity of output conditional on each shock in each variant of the model, which provides a measure of the potency of particular fiscal instruments for stabilizing output in face of a particular shock. The labor tax adjustment model generates the highest tax

[8]However, in these models, the presence of one specific rule for each tax rate makes the comparison difficult.

elasticity of output, then the capital tax model, followed by the consumption and lump-sum tax models. This ranking applies for any shock and is robust to changes in the total horizon considered in the calculation of the elasticity. Fiscal policy exhibits maximum efficacy to stabilize output fluctuations in the aftermaths of markup shocks (wage and cost push) and technology shocks (neutral and investment efficiency). These findings highlight the well-known role of the labor wedge in the propagation of shocks over the business cycle.

Although the effects of fiscal policy adjustments are quantitatively small, the implementation does matter. In fact, we do find that the baseline labor tax model allows to achieve output stabilization without requiring too much volatility in tax revenues and public debt. In other words, the positive properties of the tax system are strongly affected by the implementation. Whereas this is innocuous from a positive point of view, it ought to have strong implications for a normative analysis. Although such an analysis is beyond the scope of this paper, two points are worth mentioning. The presence of a time varying labor (or capital or consumption) tax adds an additional time varying distortion to the model beyond the price and wage markups, which can add to the welfare cost of fluctuations for the agents. Second, in a world where the central bank takes fiscal policy as given, the presence of a time varying tax rate can bring back an inflation output stabilization trade-off that would affect the shape of optimal monetary policy.

To provide better understanding of debt financing dynamics, the sensitivity of these findings is then assessed to alternative settings. In particular, the sensitivity to alternative fiscal rule parameterizations, the role of monetary policy, and the presence of alternative instruments (endogenous government spending). The sensitivity analysis shows that, unsurprisingly, lower output volatility is achieved when the government's fiscal rule allows for a greater focus on the output stabilization. As government's concern for the debt stabilization increases the fiscal policy potency improves –as indicated by the output elasticities which rises for each shock. Higher concern for output stabilization by the central bank sees positive spillovers from monetary to fiscal policy grow –the fiscal authority needs less to worry about stabilizing the output and is thus freer to focus on debt stabilization.

In other words, the fiscal policy potency is improved for all the shocks –with a sole exception of a wage markup shock– as confirmed by higher output elasticities. Fiscal policy potency is reduced, although marginally, under monetary policy rule in which the interest rate does not respond to the output gap. Moreover, the results show that endogenous government spending used to achieve debt financing improves the fiscal policy potency, but it leads to the more volatile output, unconditional of any shocks hitting the economy. These results are found to be robust to the exclusion of nominal wage rigidities.

The remainder of the paper is organized as follows. Section 2 presents the model. Section 3 describes the econometric framework of the analysis. Section 4 discusses the parameterization of the model including the posterior estimates. Section 5 discusses the positive implications of the tax instrument choice used to finance the stabilization policy –in particular, the role of this decision is assessed on the propagation of shocks and the volatility of the business cycle. Section 6 conducts a sensitivity analysis of the results to alternative monetary and fiscal policies, and to nominal rigidities. A last section concludes.

2.2 The Model

This section presents a standard dynamic stochastic general equilibrium (DSGE) model à la Smets and Wouters (2007) or Justiniano, Primiceri, and Tambalotti (2010) extended to the presence of explicit fiscal stabilization policy. Stabilization policy is modeled as a tax income rule which reacts both to fluctuations in output, and the debt/ouptut ratio. We then consider situations where increases in tax revenues can be achieved by adjusting the lump sum component of the tax or either a labor, a capital or a consumption tax.

Fluctuations are driven by six orthogonal structural shocks as in Smets and Wouters (2007) plus two fiscal shocks. The shocks include total factor productivity shocks, two shocks that affect the intertemporal margin (risk premium shocks and investment–specific technology shocks), two shocks that affect the intratemporal margin (wage and price mark–up shocks), and three policy shocks (exogenous government spending, fiscal receipts, and monetary policy shocks).[9]

2.2.1 Labor Market

Following Erceg, Henderson, and Levin (2010), each household $j \in (0,1)$ is assumed to supply a specialized labor, $L_t(i)$ to a fully competitive "employment agency" –hereafter dubbed as the labor packer, which combines these differentiated labor inputs to produce a composite homogeneous labor service, L_t, by using the following Dixit–Stiglitz aggregator

$$L_t = \left(\int_0^1 L_t(j)^{\frac{1}{1+\varepsilon_t^w}} \mathrm{d}i \right)^{1+\varepsilon_t^w}. \tag{2.1}$$

$\varepsilon_t^w > 1$ is the desired markup of wages over the household's marginal rate of substitution. Following Smets and Wouters (2007), ε_t^w is assumed to be time varying, subject to stochastic shocks, and follows the ARMA(1,1) process

$$\log \varepsilon_t^w = \rho_w \log \varepsilon_{t-1}^w + (1-\rho_w) \log \overline{\varepsilon}^w + \epsilon_t^w - \theta_w \epsilon_{t-1}^w, \tag{2.2}$$

where $|\rho_w| < 1$, $|\theta_w| < 1$, $\overline{\varepsilon}^w > 0$ and $\epsilon_t^w \sim N(0, \sigma_w)$. A positive realization of ϵ_t^w drives the wage upward, and is the equivalent to a cost-push shock in the standard New-Keynesian Phillips curve.

The demand for labor of type j– as obtained by cost minimizing the total wage bill, $\int_0^! W_t(j) L_t(j) \mathrm{d}j$, and taking as given the individual wage costs of household i, $W_t(j)$– is given by

$$L_t(j) = \left(\frac{W_t(j)}{W_t} \right)^{-\frac{1+\varepsilon_t^w}{\varepsilon_t^w}} L_t \tag{2.3}$$

The aggregate wage, derived from the zero-profit condition of a labor packer, is

$$W_t = \left(\int_0^1 W_t(j)^{-\frac{1}{\varepsilon_t^w}} \mathrm{d}j \right)^{-\varepsilon_t^w} \tag{2.4}$$

The homogeneous labor is then supplied to intermediate goods producing firms to use in the intermediate goods production.

[9] The companion technical appendix details the analytical derivation of the model.

2.2.2 Households

Each infinitely lived household $j \in (0,1)$ has preferences over consumption, C_t, and leisure represented by the following intertemporal utility function[10]

$$E_t \sum_{t=0}^{\infty} \beta^t \varepsilon_t^b \left(\log(C_t - \chi C_{t-1}) - \vartheta \frac{L_t(j)^{1+\nu}}{1+\nu} \right) \tag{2.5}$$

where $\beta \in (0,1)$ denotes the psychological discount factor, $\nu \geq 0$ is the inverse of the Frisch elasticity of labor supply, $\vartheta > 0$ is a constant and the habit parameter $\chi \in [0,1]$ measures the degree of habit persistence in consumption. ε_t^b is an intertemporal preference shock that is assumed to follow the AR(1) stochastic process

$$\log \varepsilon_t^b = \rho_b \log \varepsilon_{t-1}^b + \epsilon_t^b, \quad \epsilon_t^b \sim N(0, \sigma_b) \tag{2.6}$$

where $|\rho_b| < 1$ and $\epsilon_t^b \sim N(0, \sigma_b)$.

The household enters a period with financial wealth B_{t-1}, that yields a gross nominal return R_{t-1}, earns the nominal wage $W_t(j)$ per hour of work $L_t(j)$, pays a proportional labor tax $\tau_t^w \in (0,1)$, such that the total after tax labor income is given by $(1-\tau_t^w)W_t(j)L_t(j)$.

The household leases a flow of capital services K_t^s at the after–tax rental rate $P_t R_t^k (1-\tau_t^k)$, where $\tau_t^k \in (0,1)$ denotes the capital income tax. Capital services are given by $K_t^s = Z_t K_t$, where Z_t is the utilization rate of the household i's capital stock K_t. Thus, the after-tax capital income is $(1-\tau_t^k)R_t^k Z_t K_t$. Each household also receives a share of the profits in the economy, Π_t, and a lump–sum transfer, T_t, from the government. This income is then used to consume, C_t, which is subject to a consumption tax $\tau_t^c \in (0,1)$, invest, I_t, purchase assets, B_t, as a way to transfer wealth towards the next period and pay for a resource costs, $\Phi_z(Z_t)K_t$, associated with utilization of capital. The utilization cost function $\Phi_z(Z)$ is assumed to be increasing, convex and satisfies $\Phi_z(1) = 0$ and $\Phi_z''(1)/\Phi_z'(1) = \sigma_z > 0$. Under these

[10] To save on notations, and because the household are ex-post identical, the index j will be omitted in the sequel. It will only be preserved for labor as a way to remind the reader about the existence of differentiated labor inputs.

assumptions, the dynamics of the model depends on σ_z while its steady–state does not.

She, therefore, faces the intertemporal budget constraint (expressed in real terms) given by

$$\begin{aligned}(1+\tau_t^c)C_t + I_t + \frac{B_t}{R_t P_t} \leq & \frac{B_{t-1}}{P_t} + (1-\tau_t^w)\frac{W_t(j)L_t(j)}{P_t} \\ & + (1-\tau_t^k)R_t^k K_t Z_t - \Phi_z(Z_t)K_t + \frac{\Pi_t}{P_t} + T_t \end{aligned} \tag{2.7}$$

The level of gross investment, I_t, leads to formation of the capital stock, K_t, which evolves according as

$$K_{t+1} = \varepsilon_t^i \left(1 - \Phi_i\left(\frac{I_t}{I_{t-1}}\right)\right) I_t + (1-\delta)K_t \tag{2.8}$$

where $\delta \in (0,1)$ denotes the rate of depreciation of capital. Implicit in Equation (2.8) is that changes in the investment decision are subjected to increasing and convex adjustment costs, $\Phi_i(\cdot)$, à la Christiano, Eichenbaum, and Evans (2005b). These costs satisfy $\Phi_i(1) = \Phi_i'(1) = 0$, such that these costs are inoperative in the steady state, and $\varphi \equiv \Phi_i''(1) > 0$. ε_t^i is an investment shock that shifts the efficiency with which the final good can be turned into physical capital. It is assumed to follow the exogenous AR(1) process

$$\log \varepsilon_t^i = \rho_i \log \varepsilon_{t-1}^i + \epsilon_t^i, \tag{2.9}$$

where $|\rho_i| < 1$ and $\epsilon_t^i \sim N(0, \sigma_i)$.

Each household i chooses her consumption C_t, bond holdings B_t, investment I_t and capital utilization Z_t by maximizing her utility (2.5) subject to her intertemporal budget constraint (2.7) and capital accumulation constraint (2.8).[11]

2.2.3 Firms

Final Goods–Producing Firm

There exists a representative, perfectly competitive, firm that produces a final homogenous good that can be either consumed, privately or publicly, or invested.

[11] Since the model features nominal wage rigidities, we defer the determination of the labor decision to a later section.

The final good is obtained by combining a continuum of continuum of intermediate goods, $Y_t(i)$, $i \in (0,1)$, according to the technology

$$Y_t = \left(\int_0^1 Y_t(i)^{\frac{1}{1+\varepsilon_t^p}} \mathrm{d}i \right)^{1+\varepsilon_t^p} \tag{2.10}$$

where $\varepsilon_t^p > 0$ is the desired markup of prices of each intermediate good, $P_t(i)$, over its marginal cost. Like the wage markup, it is assumed that the price markup is subject to stochastic shocks modeled as an ARMA(1,1) process

$$\log \varepsilon_t^p = (1 - \rho_p) \log \overline{\varepsilon}^p + \rho_p \log \varepsilon_{t-1}^p - \theta_p \epsilon_{t-1}^p + \epsilon_t^p, \tag{2.11}$$

where $\rho_p \in (0,1)$, $\theta_p \in (0,1)$, $\overline{\varepsilon}^p > 0$ stands for a value of price markup in the steady state and $\epsilon_t^p \sim N(0, \sigma_p)$.

The demand for each intermediate good $Y_t(i)$, as obtained from profit maximization of the final good firm, is then given by

$$Y_t(i) = \left(\frac{P_t(i)}{P_t} \right)^{-\frac{1+\varepsilon_t^p}{\varepsilon_t^p}} Y_t \tag{2.12}$$

where P_t is the aggregate price level. Competition in the market for the final good drives the representative firm's profit to zero. The zero–profit condition, along the Equation (2.12), determines P_t as

$$P_t = \left(\int_0^1 P_t(i)^{-\frac{1}{\varepsilon_t^p}} \mathrm{d}i \right)^{-\varepsilon_t^p} \tag{2.13}$$

Intermediate Good Producers

There is a continuum of intermediate good producers that each produce, in a monopolistically competitive market, a specific intermediate good $i \in (0,1)$ by means of capital services $K_t^s(i)$, and labor, $L_t(i)$, according to the technology described by

$$Y_t(i) = \max \left\{ \varepsilon_t^a K_t^s(i)^\alpha L_t(i)^{1-\alpha} - \Phi, 0 \right\} \tag{2.14}$$

where $\alpha \in (0,1)$. The presence of the fixed cost $\Phi > 0$ implies that the technology exhibits increasing returns to scale. Φ is chose such that profits are zero in the steady state. ε_t^a is a standard technology shock that is assumed to follow

$$\log \varepsilon_t^a = \rho_a \log \varepsilon_{t-1}^a + (1 - \rho_a) \log \overline{\varepsilon}^a + \epsilon_t^a, \tag{2.15}$$

where $|\rho_a| < 1$, $\bar{\varepsilon}^a > 0$ and $\epsilon_t^a \sim N(0, \sigma_a)$.

Cost minimization then implies that the optimal capital labor ratio is given by

$$\frac{K_t^s(i)}{L_t(i)} = \frac{\alpha}{1-\alpha}\frac{W_t}{R_t^k} \tag{2.16}$$

which is independent from the firm ($K_t^s(i)/L_t(i) = K_t^s/L_t$).

The real marginal cost, $MC_t(i)$ is given by

$$MC_t(i) = \frac{W_t^{1-\alpha} R_t^{k\,\alpha}}{\alpha^\alpha (1-\alpha)^{1-\alpha} \varepsilon_t^a} \tag{2.17}$$

and is also independent from the firm's type.

2.2.4 Price and wage setting

Price setting

Intermediate good firms set their price according to a standard Calvo (1983) price setting scheme. In each period a individual firm has a probability $\xi_p \in [0,1]$ of getting a chance to reset its price. When it is not selected to re-optimize, the firm charges $P_t(i) = \pi_{t-1}^{\iota_p} \bar{\pi}^{1-\iota_p} P_{t-1}(i)$, where $\iota_p \in [0,1]$ controls the degree with which prices are indexed on past inflation as opposed to steady state inflation. A firm that resets its price in period t selects to so as to maximize its future expected discounted profits

$$\max_{P_t(i)} E_t \left[\sum_{s=0}^{\infty} (1-\xi_p)^s \Psi_{t,t+s} \left[\Omega_{t,t+s}^p \widetilde{P}_t(i) - MC_{t+s} \right] Y_{t+s}(i) \right] \tag{2.18}$$

subject to the total demand it faces as given by Equation (2.12).[12] In the latter expression, $\Omega_{t,t+s}^p$ denotes the nominal growth component of the price setting behavior

$$\Omega_{t,t+s}^p \equiv \begin{cases} 1 & \text{if } s = 0 \\ \Omega_{t,t+s-1}^p \pi_{t+s-1}^{\iota_p} \bar{\pi}^{1-\iota_p} & \text{if } s > 0 \end{cases} \tag{2.19}$$

and $\Psi_{t,t+s} \propto \frac{\beta^s \Lambda_{t+s}}{\Lambda_t}$ denotes the proper stochastic discount factor.

[12] As shown in the companion technical appendix to this paper, the price setting behavior of each firm i is independent from its type, $\widetilde{P}_t(i) = \widetilde{P}_t$.

Using Equation (2.13) together with price indexation scheme (2.19) and the Calvo assumption, the aggregate price index rewrites as

$$P_t = \left(\xi_p \widetilde{P}_t^{-\frac{1}{\varepsilon_t^p}} + (1-\xi_p)(\pi_{t-1}^{\iota_p} \overline{\pi}^{1-\iota_p} P_{t-1})^{-\frac{1}{\varepsilon_t^p}} \right)^{-\varepsilon_t^p} \tag{2.20}$$

Wage setting

Just like intermediate good firms, households set their price infrequently á la Calvo (1983). In each period, household j gets a chance to reset its wage with probability ξ_w. If she cannot reset it, her wage is indexed on steady-state and past inflation, such that $W_t(i) = \pi_{t-1}^{\iota_w} \overline{\pi}_{t-1}^{1-\iota_w}(i)$ where $\iota_w \in (0,1)$ controls for the degree with which non–reoptimized wages are indexed on past inflation. Household j chooses her optimal wage $\widetilde{W}_t(j)$ so has to maximize the utility value of labor

$$\max_{\widetilde{W}_t(j)} E_t \left[\sum_{s=0}^{\infty} (\beta(1-\xi_w))^s \left(\Lambda_{t+s}(1-\tau_{t+s}^w)\Omega_{t,t+s}^w \widetilde{W}_t(j) L_{t+s}(j) - \frac{L_{t+s}(j)^{1+\nu}}{1+\nu} \right) \right] \tag{2.21}$$

subject to the demand for labor of type j (Equation 2.3). In the latter equation, Λ_{t+j} is the marginal utility of wealth (the Lagrangian multiplier of household problem that converts the wage revenue into utility terms) and where $\Omega_{t,j}^w$ is defined as

$$\Omega_{t,t+s}^w \equiv \begin{cases} 1 & \text{if } s = 0 \\ \Omega_{t,t+s-1}^w \pi_{t+s-1}^{\iota_w} \overline{\pi}^{1-\iota_w} & \text{if } s > 0 \end{cases} \tag{2.22}$$

Using Equation (2.4) together with price indexation scheme (2.22) and the Calvo assumption, the aggregate price index rewrites as

$$W_t = \left(\xi_w \widetilde{W}_t^{-\frac{1}{\varepsilon_t^w}} + (1-\xi_w)(\pi_{t-1}^{\iota_w} \overline{\pi}^{1-\iota_w} W_{t-1})^{-\frac{1}{\varepsilon_t^w}} \right)^{-\varepsilon_t^w} \tag{2.23}$$

The markup of the aggregate wage over the wage received by the households is distributed to the households in the form of dividends (see Equation (2.7)).

2.2.5 Monetary authority

The monetary authority conducts monetary policy according to a standard Taylor rule, and therefore adjusts short–term nominal interest rate, R_t, in response to deviation of inflation, π_t, from its steady–state value and changes in the level of the output gap. The output gap is defined as the difference between actual and natural output. Consistent with DSGE model, natural output is defined as the level of output that would prevail under flexible prices and wages and in the absence of the two "mark–up" shocks. The monetary policy is assumed to be described by the simple Taylor–type interest rate rule

$$R_t = \rho_r R_{t-1} + (1 - \rho_r)\left(\overline{R} + \kappa_y \log\left(\frac{Y_t}{Y_t^F}\right) + \kappa_\pi \log\left(\frac{\pi_t}{\overline{\pi}}\right)\right) + \varepsilon_t^R \tag{2.24}$$

where $\kappa_y \in \mathbb{R}_+$ and $\kappa_\pi > 1$. $\overline{R}$ is the steady state nominal rate (gross rate) and Y_t^F denotes the level of output attained in the flexible price allocation –*i.e.* the natural output. The parameter $\rho_r \in [0, 1]$ captures the degree of interest rate smoothing. Finally, it is assumed that the monetary policy shocks ε_t^r follow a first–order autoregressive process with an i.i.d. normal error term

$$\log \varepsilon_t^R = \rho_r \log \varepsilon_{t-1}^R + \epsilon_t^R, \tag{2.25}$$

where $|\rho_R| \in (0, 1)$ and $\epsilon_t^R \sim N(0, \sigma_r)$.

2.2.6 The Government

The fiscal authority collects tax revenue F_t and issues public bonds B_t as a way to finance an exogenously given sequence of government spending $\{G_t\}_{t=0}^{\infty}$ and service the debt. The government budget constraint is, thus, of the form

$$B_t + P_t F_t = R_{t-1} B_{t-1} + P_t G_t \tag{2.26}$$

The government spending is an exogenous stochastic AR(1) process which, following Smets and Wouters (2007), responds to productivity developments

$$\log g_t = (1 - \rho_g) \log \overline{g} + \rho_g \log g_{t-1} + \rho_{ga} \epsilon_t^a + \epsilon_t^g, \tag{2.27}$$

where $|\rho_g| \in (0, 1)$, $\rho_{ga} \in \mathbb{R}$, $\overline{g} > 0$ and $\epsilon_t^g \sim N(0, \sigma_g)$.

Tax revenue, or fiscal receipts, F_t are composed of consumption tax revenue, $\tau_t^c C_t$, wage tax revenue, $\tau_t^w W_t L_t$, capital tax revenue, $\tau_t^k R_t^k K_t$, and lump–sum tax revenue, T_t, such that

$$F_t = \tau_t^c C_t + \tau_t^w \frac{W_t}{P_t} L_t + \tau_t^k R_t^k K_t + T_t \tag{2.28}$$

Policymakers are assumed to use the proceeds from taxation to control the path of public debt. More precisely, the government uses the proposed rule to set the level of fiscal receipts to stabilize the output around its steady state level while ensuring the fiscal sustainability by stabilizing debt/output ratio around its steady state. The fiscal authority sets the tax revenues according to the simple fiscal rule

$$F_t = F^\star \exp\left(\gamma_d \frac{(B_{t-1}/P_{t-1}) - \bar{b}}{\bar{b}} + \gamma_y(\log(Y_t) - \log \overline{Y}) + \varepsilon_t^f\right) \tag{2.29}$$

where $\gamma_d > 0$, $\gamma_y > 0$ and $\bar{b}$ denotes the steady state level of real debt. First, tax revenues are used to discipline the evolution of real debt (deflated for growth) and ensures its sustainability by ensuring that any positive (negative) deviations of the debt/output ratio from its steady state level leads to an increase (decrease) in tax revenues collected by the government ($\gamma_d > 0$). Second, the rule also attempts to stabilize the business cycle as any positive (negative) deviation of the output from its steady state leads to an increases (decrease) in tax revenue that the government should collect ($\gamma_y > 0$). The term ε_t^f captures the discretionary component of fiscal policy which evolves according to an exogenous first–order autoregressive process

$$\varepsilon_t^f = \rho_f \varepsilon_{t-1}^f + \epsilon_t^f, \tag{2.30}$$

where $|\rho_f| \in (0,1)$ and $\epsilon_t^f \sim N(0, \sigma_f)$. Note that contrary to the existing literature that stipulates a rule for each individual tax instrument (see for example Leeper, Plante, and Traum (2010)), this policy rather expresses the rule in terms of the overall government's behavior. In particular, as long as government spendings are set exogenously, this rule can be given a "deficit rule" interpretation. One motivation for such a simple rule is that most governments rather have primary deficit objectives –*i.e.* have an implicit deficit rule, that they finance by endogenously adjusting the tax system. This is exactly what we do in this paper, as the policymaker is assumed to set the total tax revenues according the specified rule, and then let the tax system adjust to ensure that the budget constraint is satisfied. Which of the tax should be adjusted is *a priori* indeterminate in a positive context.[13] Following Tinbergen's rule, only one instrument, at the time, is used to achieve this increase in tax revenues, holding all other tax rates (and the lump sum tax) constant. For example, to implement the rule by labor tax adjustment then only labor tax is allowed to vary and all the other ones are kept constant.

The fiscal setup outlined here allows to separate the problem of stabilization from that of implementation, thus, providing with a more structured framework to understand these two aspects of fiscal policy. The question of the implementation is important as different tax instruments may lead to different outcomes both in terms of potency and efficiency.

2.2.7 General Equilibrium

A competitive general equilibrium is a sequence of rates of return,$\mathscr{R}_t \equiv \{R^k_{t+i}, R_{t+i}\}_{i=0}^{\infty}$, a sequence of prices $\mathscr{P}_t \equiv \{P_{t+i}\}_{i=0}^{\infty}$, a sequence of wages $\mathscr{W}_t \equiv \{W_{t+i}\}_{i=0}^{\infty}$, a sequence of taxes $\mathscr{T}_t \equiv \{\tau^w_{t+i}, \tau^c_{t+i}, \tau^k_{t+i}, T_{t+i}\}_{i=0}^{\infty}$, a sequence of policy instruments $\mathscr{G}_t \equiv \{G_{t+i}, F_{t+i}\}_{i=0}^{\infty}$ and a sequence of quantities $\mathscr{Q}_t \equiv \{C_{t+i}, Y_{t+i}, Z_{t+i}, K_{t+i}, L_{t+i}, B_{t+i}\}_{i=0}^{\infty}$ such that

1. for a given sequence of rates of return, $\mathscr{R}_t$, a sequence of prices, $\mathscr{P}_t$, a sequence of wages, $\mathscr{W}_t$, a sequence of taxes, $\mathscr{T}_t$, and a sequence of quantities, $\mathscr{Q}_t$, the sequence of policy instruments, $\mathscr{G}_t$, is set as Equations (2.27) and (2.29);

2. for a given sequence of rates of return, $\mathscr{R}_t$, a sequence of prices, $\mathscr{P}_t$, a sequence of wages, $\mathscr{W}_t$, a sequence of taxes, $\mathscr{T}_t$ and a sequence of policy instruments, $\mathscr{G}_t$, the sequence of quantities, $\mathscr{Q}_t$, solves the optimization problems of the agents;

3. for a given sequence of returns, $\mathscr{R}_t$, a sequence of prices, $\mathscr{P}_t$, a sequence of taxes, $\mathscr{T}_t$, a sequence of policy instruments, $\mathscr{G}_t$, and a sequence of quantities, $\mathscr{Q}_t$, the sequence of wages, $\mathscr{W}_t$, is set according to the wage setting process;

[13] Note that one may also ask the question of the optimal tax adjustments. Although this question is of interest, this is beyond the scope of the current paper that rather wants to investigate the implications of using alternative taxes to balance the budget.

4. for a given sequence of returns, $\mathscr{R}_t$, a sequence of wages, $\mathscr{W}_t$, a sequence of taxes, $\mathscr{T}_t$, a sequence of policy instruments, $\mathscr{G}_t$, and a sequence of quantities, $\mathscr{Q}_t$, the sequence of prices, $\mathscr{P}_t$, is set according to the price setting process;

5. for a given sequence of wages, $\mathscr{W}_t$, a sequence of prices, $\mathscr{P}_t$, a sequence of taxes, $\mathscr{T}_t$, a sequence of policy instruments, $\mathscr{G}_t$, and a sequence of quantities, $\mathscr{Q}_t$, the sequence of returns, $\mathscr{R}_t$, clear the capital and bond markets;

6. for a sequence of quantities, $\mathscr{Q}_t$, a sequence of rates of return, $\mathscr{R}_t$, a sequence of wages, $\mathscr{W}_t$, a sequence of prices, $\mathscr{P}_t$ and a sequence of policy instruments, $\mathscr{G}_t$, the sequence of taxes, $\mathscr{T}_t$, implies that the government budget constraint is satisfied.

2.3 Econometric framework

This section describes the econometric framework of the analysis. The present model is estimated with Bayesian maximum likelihood in the frequency domain, as in Christiano and Vigfusson (2003) and Sala (2012). The benefit of this method, relative to the standard estimation in the time domain, is to guide the estimation of a model on the basis of its performance at frequencies chosen by the econometrician. In particular, in this study, we are mainly interested in the business cycle implications of fiscal stabilization policies. Therefore, we will set the focus on phenomena taking place at frequencies ranging from 6 to 32 quarters as opposed to frequencies that correspond to long-run trends.[14]

Just like in the standard approach, the set of structural parameters is estimated

[14]Standard Bayesian maximum likelihood is typically conducted in the time domain, which therefore uses all frequencies (see An and Schorfheide (2007)). But, as the model generates cross–frequency restrictions, the presence in the estimation of frequencies that the model is not intended to explain may affect the estimates (see Hansen and Sargent (1993) study the biases caused by misspecification of seasonal frequencies and Cogley (2001) focus on the misspecification of the trend component). Alternatively, the Bayesian maximum likelihood can be conducted in the frequency domain.

so as to maximize the posterior likelihood function

$$\mathcal{L}(\theta|\mathcal{Y}_T) \propto f(\theta) \times L(\theta|\mathcal{Y}_T) \tag{2.31}$$

where $\mathcal{Y}_T$ denotes the set of data (for $t = 1 \dots T$) used for estimation, θ is the vector of structural parameters to be estimated, $f(\theta)$ is the joint prior distribution of the structural parameters, and $L(\theta|\mathcal{Y}_t)$ is the likelihood of the model expressed in the frequency domain. We now detail the construction of this object.[15]

The solution of a log–linear version of the model admits the following representation

$$Y_t = M_y(\theta) X_t \tag{2.32}$$

$$X_t = M_x(\theta) X_{t-1} + M_e(\theta)\epsilon_t \tag{2.33}$$

where Y_t and X_t denote the vector of observed variables and the underlying state vector of the model, respectively; ε is the vector of the exogenous structural shocks, such that $\epsilon_t \sim N(0, \Sigma_e)$; $M_y(\theta)$ and $M_x(\theta)$ are matrices whose elements are (non–linear) functions of the structural parameters θ; and finally $M_e(\theta)$ is an impact matrix that describes how each of the structural shocks impacts on the state vector.

The aim, here, is to identify a vector of deep parameters θ that explains most of the business cycle at the 6 to 32 quarters frequencies. To this goal, the share of volatility of variable y_t at 6–32 quarters frequency is computed. The spectral density of the vector Y_t is given by

$$S_Y(\omega, \theta) = \frac{1}{2\pi} M_y(\theta)(I - M_x(\theta)e^{-i\omega})^{-1} M_e(\theta)\Sigma_e M_e(\theta)'(I - M_x(\theta)'e^{i\omega})^{-1} M_y(\theta)' \tag{2.34}$$

where $\omega \in [0, 2\pi]$. As shown in Harvey (2003), the log–likelihood function of the state–space system (2.32)-(2.33) is asymptotically given by

$$\log(L(\theta, \mathcal{Y}_T)) \propto -\frac{1}{2\pi}\sum_{j=1}^{T}[\log(\det(S_Y(\omega_j;\theta))) + \mathrm{Tr}(S_Y(\omega_j;\theta)^{-1} I_Y(\omega_j))] \tag{2.35}$$

[15]This presentation closely follows Christiano and Vigfusson (2003) and Sala (2012).

where $\omega_j = 2\pi j/T$, $j = 1, \ldots, T$, $S_Y(\omega_j;\theta))$ is the spectral density of the state–space representation of the model (2.32)–(2.33) and $I_Y(\omega_j)$ is the periodogram of the observables $\mathcal{Y}_T$ evaluated at frequency ω_j. The spectral density of the model is given by

$$S_Y(\omega;\theta) = \frac{1}{2\pi} M_y(\theta)(I - M_x(\theta)e^{-i\omega})^{-1} M_e(\theta)\Sigma_e M_e(\theta)'(I - M_x(\theta)'e^{i\omega})^{-1} M_y(\theta)'' \tag{2.36}$$

where $\omega \in [0, 2\pi]$ denotes the frequency at which the spectral density is evaluated. The periodogram is computed as

$$I_Y(\omega_j) = \frac{1}{T} f(\omega_j) f(\omega_j)' \tag{2.37}$$

where

$$f(\omega_j) = \sum_{t=1}^{T} y_t e^{-i\omega t}$$

is the discrete Fourier transform of the observables y_t.

In the application, I slightly depart from this specification and rather consider the specification of the likelihood function proposed by Christiano and Vigfusson (2003)

$$\begin{aligned} \log(L(\theta, \mathcal{Y}_T)) \propto -\frac{1}{2\pi} \sum_{j=1}^{T} w(\omega_j) [&\log(\det(S_Y(\omega_j;\theta))) \\ &+ \mathrm{Tr}(S_Y(\omega_j;\theta)^{-1} I_Y(\omega_j))] \end{aligned} \tag{2.38}$$

which extends the standard likelihood to a specification where the econometrician can select the frequencies at which the model is estimated. More specifically, the weight, $w(\omega_j)$, can be obtained from the spectral gain associated to a particular filter (provided that data are treated the same way). In this case the weight, $w(\omega_j)$, is the square of the gain at frequency ω_j. The weight is acquired by using a rectangular window that assigns a unit weight to frequencies $\omega \in [\underline{\omega}; \overline{\omega}]$ and zero otherwise. This amounts to apply an ideal bandpass filter to both the data and the model. Following Christiano and Vigfusson (2003) and Sala (2012), the estimation is conducted for a band of frequencies that focuses on phenomena taking place between 6 and 32 quarters. Therefore,

$$w(\omega_j) = \begin{cases} 1 & \text{if } \frac{2\pi}{32} \leq \omega_j \leq \frac{2\pi}{6} \\ 0 & \text{otherwise} \end{cases}$$

2.4 Estimation Results

2.4.1 Data

The eight variables used in estimation are: $\Delta \log(Y_t)$, $\Delta \log(C_t)$, $\Delta \log(I_t)$, $\Delta \log(W_t)$, $\Delta \log(F_t)$, L_t, π_t, R_t. They are matched with the following key macroeconomic quarterly US time series, for the period 1960Q1–2007Q4: the log difference of real GDP, real consumption, real investment, the real wage, log difference of real fiscal receipts, log hours worked, the log difference of the GDP deflator, and the federal funds rate. The sticky–price model is estimated on the basis of all these eight variables. A full description of the data used is given in Appendix 2.A.

2.4.2 Estimated and calibrated parameters

Priors

Not all structural parameters are estimated. These values were kept fixed because of identification problems. Table (2.1) presents the values assigned to the such parameters.[16] The discount factor, β, is fixed at 0.99, which implies an annual steady state interest rate of 4%. The capital share parameter, α, is set equal to 0.3, which implies a labor share of 70%. The annual steady state depreciation rate is 10%, implying that δ equals to 0.025. In addition, to match postwar U.S. data the ratios of government spending and debt–to–output are set equal to 0.2 and 0.6, respectively. Additionally, the steady–state tax rates are set equal to the mean values of the data set used by Leeper, Plante, and Traum (2010) in their study of

[16] One way to interpret this restriction is to view these parameters as estimated, assuming very tight priors.

fiscal rules and are specified in Table (2.1). Finally the steady state price and wage markups are set to 10%.

Table 2.1: Calibrated parameters for the estimated model

Parameter	Role	Value
$\bar{\varepsilon}^p$	Price Markup	0.100
$\bar{\varepsilon}^w$	Wage Markup	0.100
β	Discount Rate	0.990
δ	Depreciation Rate of Capital	0.025
B/Y	Debt to Output Ratio	0.600
G/Y	Government Spending to Output Ratio	0.200
τ^k	Capital Income Tax Rate	0.184
τ^w	Labour Income Tax Rate	0.223
τ^c	Consumption Tax Rate	0.028

The remaining 14 structural parameters are estimated: the elasticity of utilization rate to the rental rate of capital, σ_z; the elasticity of the investment adjustment cost function, φ; the habit parameter, χ, and the labor supply elasticity, ν; the wage and price rigidity parameters, ξ_w and ξ_p; the wage and price indexation parameters, ι_w and ι_π; the monetary policy parameters ρ_R, κ_π, and κ_y; and the fiscal policy parameters ρ_f, γ_y, and γ_d. In addition, the autoregressive parameters of the exogenous disturbances and the standard deviations of the innovations are estimated.

The first three columns in Tables 2.2 and 2.3 report the priors used in the estimation for the parameters in the four models. The priors are similar to those commonly used in the literature (see Smets and Wouters (2007), Leeper, Plante, and Traum (2010), Forni, Monteforte, and Sessa (2009), for example).

The priors of utilization rate elasticity, φ, and the habit persistence parameter, χ, are both beta distributed with mean 0.50 and standard deviation 0.20, while the capital adjustment cost prior, ϕ, is gamma distributed with mean 4 and standard deviation 1.50. The prior of the inverse elasticity of labor supply, ν, is gamma distributed with mean 2.00 and standard deviation 0.75.

The two Calvo parameters for price and wage adjustment, ξ_π and ξ_w, are assigned beta priors with means 0.50 and standard deviation 0.10, while the price and wage indexation parameters, ι_π and ι_w, respectively, are given a beta distribution with mean 0.50 and standard deviation 0.15.

The response of the nominal interest rate to inflation, κ_π, in the monetary policy rule is given a normal distributed prior with mean 1.50 and standard deviation of 0.25, while the response to the output gap, κ_y, is given a gamma distributed prior with mean 0.12 and standard deviation 0.05. These priors are consistent with original Taylor's estimates. The coefficient of the lagged interest rate, ρ_R, is assigned a beta distributed prior with mean 0.75 and standard deviation 0.10.

The coefficient on the debt–to–output share, γ_d, and the coefficient on the output gap in the fiscal policy rule, γ_y, are both given a normal distributed prior with mean 0.50 and standard deviation 0.25.

The priors on the stochastic processes are harmonized as much as possible. All persistence parameters of the AR(1) processes are beta distributed with mean 0.7 and standard deviation 0.1. Finally, for the standard deviation of the shock innovations, the inverse gamma priors with mean 1.00 and standard deviation 4 are assigned, which corresponds to somewhat loose priors.

As often done in the literature (for example, see Sala (2012) and Justiniano, Primiceri, and Tambalotti (2010)), few shocks are normalized before estimation. The price markup, ε_t^p, and wage markup, ε_t^w, shocks are normalized so that they have a unitary impact on price and wage inflation, respectively.

Posterior

Sims' optimization routine `csminwel` is used to maximize the posterior log-likelihood function. We then generate the posterior distribution of the parameters' estimates based on the random–walk Metropolis–Hasting MCMC algorithm (see An and Schorfheide (2007)). 2 Markov chains of length 100,000 draws each are generated with a burn–in sample of 10,000 draws (retaining one every twenty subsequent draws). The number of draws is sufficient to ensure the convergence of Markov chain (see companion technical appendix).

Four versions of the model are estimated:

(i) only lump–sum tax adjusts,

(ii) only labor tax adjusts,

(iii) only capital tax adjusts,

(iv) only consumption tax adjusts.

In each case, all other taxes are held constant at their steady state value. The posteriors of all the parameters of four models are reported in the last four columns of Tables 2.2 and 2.3. The posterior for both exogenous processes and structural parameters are broadly robust across all four models (with the exception of the investment innovation standard deviation, σ_i and adjustment cost parameter φ). Further, the results point that the labor tax adjusting model is a preferred model as indicated by the log–likelihood of the posterior distribution. For instance the odds that the data support the labor tax adjustment model against the lump-sum tax model (resp. the capital tax and the consumption tax models) are 94.7% (resp. 97.8% and 61.1%). Overall, the data are quite informative about the structural parameters, as indicated by narrow confidence intervals of the posterior distribution and the significant deviation of the posteriors from their prior values.

A number of observations are worth noting regarding the estimated processes for the exogenous shock variables (see Table 2.2). Overall, the data appear to be very informative on the stochastic processes for the exogenous disturbances. However, the persistence parameters are lower compared to the standard literature. For instance the persistence of the technology shock is about 0.65 in all models, while other estimations report persistence of about 0.95. There are two reasons for this result. Firstly, the presence of the fiscal rule, and the associated smoothing, already accounts for some persistence in dynamics. Secondly, the focus on business cycle frequencies also explains the lower persistence of parameters: the model does not need to account for some medium run frequency phenomena observed in the behavior of hours worked, interest rates and the inflation rate. As a way to assess the relevance of these findings, I directly estimated the process for the total factor productivity, focusing on frequencies ranging from 6 to 32 quarters. The mean of the posterior distribution for the persistence parameter is 0.62.

The volatility of all innovations are lower than reported by Smets and Wouters (2007). Again, the explanation is to be found in the fact that only business cycle frequencies are considered in the present paper. This is consistent with Sala's (2012) findings which indicate that the volatility of shocks decreases when attention is restricted to business cycle phenomena.

Insofar as the preference, technology, and monetary parameters of the model are concerned, our estimates are close to previous estimates in the literature. The estimates of the elasticity of labor supply ν vary across the models with smaller estimates reported for a lump-sum and consumption tax and highest for the labor tax adjustments. I estimate the value of ν of 1.242 for the model where only labor taxes adjust (for models where other taxes adjust the estimates tend to be lower –with lowest estimate of 0.7327 for a capital tax adjustment). When wages are flexible the marginal rate of substitution between consumption and labor equals the real wage. Therefore, large values of this elasticity are needed to match the observed fluctuations in hours worked. In a setting with both price and wage nominal rigidities, real wages are sluggish, so most of the adjustments on the labor market are made by hours worked, which are then more volatile for lower values of ν. The posterior estimate for the elasticity of the investment adjustment cost, φ, in the capital tax model reflects the lack of identification of this parameter in that version of the model, as variations in the capital tax actually capture fluctuations in the capital wedge, that are otherwise absorbed by the marginal adjustment cost. Hence the posterior mean of φ is 3.9133, to be compared to its prior value of 4. In all other models, the capital tax is held fixed, and the adjustment cost parameter can then be properly identified. The posterior mean of φ is then lower than its prior value, suggesting a faster response of investment (its estimate is 1.7716 for the labor tax adjusting model). Finally, the posterior mean of the elasticity of the marginal utilization cost function, σ_z, is also identified as its posterior mean is significantly higher (0.7363) than its prior value.

Table 2.2: Posterior Results (Forcing Variables Processes)

	Priors			Posterior (Tax Model)			
	Dist.	Mean	Std. Dev.	Lump Sum	Labor	Capital	Consumption
ρ_a	B	0.70	0.10	0.6430	0.6415	0.6660	0.6449
				[0.6045,0.6854]	[0.6034,0.6849]	[0.6299,0.7092]	[0.6056,0.6902]
ρ_g	B	0.70	0.10	0.7590	0.7527	0.7668	0.7632
				[0.7305,0.7959]	[0.7235,0.7907]	[0.7390,0.8021]	[0.7337,0.8006]
ρ_i	B	0.70	0.10	0.5800	0.5825	0.5787	0.5953
				[0.5437,0.6226]	[0.5448,0.6239]	[0.5416,0.6186]	[0.5574,0.6336]
ρ_p	B	0.70	0.10	0.8266	0.8281	0.8325	0.8234
				[0.8038,0.8631]	[0.8074,0.8638]	[0.8117,0.8665]	[0.8008,0.8587]
ρ_r	B	0.70	0.10	0.5389	0.5304	0.5341	0.5430
				[0.4886,0.5863]	[0.4802,0.5784]	[0.4835,0.5805]	[0.4934,0.5892]
ρ_h	B	0.70	0.10	0.8825	0.8901	0.8738	0.8829
				[0.8674,0.9097]	[0.8771,0.9172]	[0.8570,0.9046]	[0.8692,0.9116]
ρ_b	B	0.70	0.10	0.6295	0.6442	0.6324	0.6194
				[0.5957,0.6719]	[0.6104,0.6845]	[0.6001,0.6737]	[0.5864,0.6598]
ρ_f	B	0.70	0.10	0.7740	0.7633	0.7692	0.7695
				[0.7472,0.8133]	[0.7350,0.8032]	[0.7418,0.8076]	[0.7421,0.8095]
σ_a	IG	1.00	∞	0.6382	0.6471	0.6340	0.6359
				[0.5939,0.6695]	[0.6002,0.6797]	[0.5892,0.6615]	[0.5917,0.6650]
σ_g	IG	1.00	∞	1.9983	2.0124	1.9652	1.9910
				[1.8644,2.0845]	[1.8625,2.1016]	[1.8271,2.0491]	[1.8458,2.0785]
σ_i	IG	1.00	∞	4.6687	4.0850	6.5961	5.2869
				[2.8264,5.2962]	[2.5772,4.5452]	[5.0422,7.4063]	[3.9489,6.4359]
σ_p	IG	1.00	∞	0.6814	0.6639	0.6783	0.6850
				[0.5910,0.7223]	[0.5867,0.7056]	[0.5969,0.7159]	[0.5961,0.7255]
σ_r	IG	1.00	∞	0.4551	0.4489	0.4512	0.4449
				[0.4230,0.4759]	[0.4186,0.4698]	[0.4195,0.4723]	[0.4152,0.4656]
σ_h	IG	1.00	∞	0.7240	0.7866	0.7067	0.7361
				[0.6397,0.7637]	[0.6873,0.8357]	[0.6311,0.7474]	[0.6566,0.7803]
σ_b	IG	1.00	∞	1.6254	1.7184	1.6117	1.8981
				[1.4392,1.7306]	[1.4885,1.8257]	[1.4305,1.7106]	[1.6794,2.0139]
σ_f	IG	1.00	∞	1.0954	1.1564	1.1588	1.1314
				[1.0027,1.1513]	[1.0542,1.2228]	[1.0576,1.2216]	[1.0327,1.1916]

Note: B: Beta distribution, IG: Gamma Inverse distribution. 68% HPDI into brackets.

Table 2.3: Posterior Results (Structural Parameters)

	Priors			Posterior (Tax Model)			
	Dist.	Mean	Std. Dev.	Lump Sum	Labor	Capital	Consumption
ρ_R	B	0.75	0.10	0.4302	0.4373	0.4424	0.4456
				[0.3929,0.4646]	[0.4007,0.4732]	[0.4062,0.4783]	[0.4080,0.4828]
κ_π	G	1.50	0.25	2.2468	2.2156	2.2596	2.2636
				[2.1224,2.3502]	[2.0919,2.3144]	[2.1307,2.3635]	[2.1407,2.3678]
κ_y	G	0.12	0.05	0.0779	0.0730	0.0804	0.0792
				[0.0604,0.0879]	[0.0573,0.0816]	[0.0624,0.0901]	[0.0611,0.0891]
ρ_F	B	0.50	0.20	0.3681	0.3064	0.3219	0.3477
				[0.3167,0.4220]	[0.2543,0.3551]	[0.2714,0.3721]	[0.2943,0.3989]
γ_y	N	0.50	0.25	0.7390	0.8298	0.8150	0.7670
				[0.6636,0.8145]	[0.7536,0.9036]	[0.7416,0.8881]	[0.6917,0.8398]
γ_d	N	0.50	0.25	0.1953	0.2168	0.2039	0.1930
				[0.1546,0.2283]	[0.1768,0.2496]	[0.1572,0.2351]	[0.1485,0.2240]
ξ_π	B	0.50	0.10	0.6327	0.6263	0.6322	0.6329
				[0.6111,0.6543]	[0.6065,0.6473]	[0.6121,0.6531]	[0.6113,0.6537]
ι_p	B	0.50	0.15	0.4009	0.3900	0.4000	0.3925
				[0.3225,0.4615]	[0.3173,0.4486]	[0.3234,0.4603]	[0.3203,0.4512]
ξ_w	B	0.50	0.10	0.6393	0.6000	0.6618	0.6304
				[0.6087,0.6745]	[0.5676,0.6348]	[0.6351,0.6920]	[0.6013,0.6637]
ι_w	B	0.50	0.15	0.4942	0.4920	0.4974	0.4966
				[0.4248,0.5647]	[0.4235,0.5599]	[0.4256,0.5675]	[0.4280,0.5628]
φ	G	4.00	1.50	2.4258	1.7716	3.9133	2.9592
				[1.1406,2.4456]	[0.8654,2.1261]	[2.9093,4.5490]	[1.9672,3.8512]
χ	B	0.50	0.20	0.6686	0.6807	0.5959	0.7219
				[0.6462,0.7402]	[0.6747,0.7697]	[0.5699,0.7116]	[0.7194,0.7855]
ν	G	2.00	0.75	0.9740	1.2421	0.7327	0.9066
				[0.6409,1.0351]	[0.8153,1.3857]	[0.5346,0.7918]	[0.6221,0.9449]
σ_z	B	0.50	0.20	0.7368	0.7363	0.7585	0.7323
				[0.6963,0.7851]	[0.6956,0.7861]	[0.7209,0.8064]	[0.6901,0.7814]
Log–Likelihood				-164.0752	-161.1933	-164.9931	-161.6464

Note: B: Beta distribution, G: Gamma distribution, N: Normal distribution. 68% HPDI into brackets.

The posterior mean of Calvo probabilities for the price and wage adjustments are in line with former estimated values. The average duration of price contracts is about 1.6 quarters, which is lower than values reported by Bils and Klenow (2002) or Steinsson and Nakamura (2013). The presence of the fiscal rule, and in particular the fact it reacts to debt, give additional persistence to the model that it does not need to pick up using nominal rigidities. Similarly, wages are re-optimized on average every 1.6 quarters. This is somewhat lower than the value reported by Smets and Wouters (2007) or Justiniano, Primiceri, and Tambalotti (2010), but close to what Christiano, Eichenbaum, and Evans (2005b) found using minimum distance estimation. The posterior mean of the monetary policy reaction function parameters is consistent with the previous estimates in the literature.

Turning the attention to the fiscal policy reaction function parameters in the labor tax adjusting model reveals that the posterior mean of γ_d and γ_y are reported to be 0.2168 and 0.8298, respectively. This implies a more aggressive fiscal response to the output gap than to public debt. The posterior estimate of γ_d implies that 1% increase in the deviations of debt share leads to an increase of 0.2168% in the fiscal revenue. The posterior mode of fiscal coefficient γ_y means that 1% deviations in the positive output gap implies that government is able to raise its tax income by 0.83%. Note that this increases tax revenue and not the tax rate itself – this is not due to the pro–cyclicality in the evolution of the tax income that the fiscal policy is countercyclical (this issue will be further discussed in the results section). Finally, fiscal revenues are not highly persistent, as indicated by the posterior mode of ρ_F (0.3064). Interestingly, these estimated values are, to a large extent, insensitive to the adjusted tax rate.

2.5 Does Implementation Matter?

This section discusses the positive implications of the choice of the tax instrument used to finance the stabilization policy. In particular we assess the role of this decision on the propagation of shocks and the volatility of the business cycle. Given that the labor tax model has been identified as the most plausible model (in terms of posterior odds), this section will focus on that particular model.

2.5.1 Contribution to the Business Cycle

This section aims at identifying the main drivers of the business cycle and investigates to what extent a change in the tax instrument that adjusts to balance the government budget constraint matters for the contribution of shocks to macroeconomic dynamics. As already indicated, results are reported for the labor tax model only. However, in order to assess the role of implementation in determining the main contributors to the business cycle, the following exercise is performed. For each draw of the Metropolis Hasting (as obtained to compute the posterior distribution of the labor tax model), the variance decomposition of output is computed for the four versions of the model described in the previous section. In other words, the variance decomposition is computed for each version using the posterior distribution of the labor tax model only. That way, this experiments measures solely the contribution of the change in the tax rate used to ensure the government budget constraint is satisfied. Table 2.4 reports the share of variance of the k-step-ahead forecast error of output attributed to individual shocks, for horizons $k = 1$, 4, 8, and 20 quarters.

Panel (a) of the Table reports the variance decomposition of output in the baseline labor tax model. Similarly to Smets and Wouters (2007) or Justiniano, Primiceri, and Tambalotti (2010) the main contributors to output volatility are the neutral technology and cost push shocks (both 16% on impact), the investment efficiency shock (27%) and the wage markup shock (22%), although for the latter the contribution becomes more sizable as the horizon increases. For instance, the wage markup shock becomes the main driver of the business cycle (55%) after 5 years. Note however that this shock plays a greater role in the short-run than in Smets and Wouters (2007) as it accounts for one-fourth of output volatility on impact (essentially zero at the same horizon in Smets and Wouters (2007)). One reason for this result is that this shock affects directly the labor wedge, which in turn has a effect on hours worked and output. This also takes place in Smets and Wouters' model, but in the present model, there is a second round of effect

Table 2.4: Variance Decomposition of output

k	a_t	g_t	ε_t^i	ε_t^π	ε_t^R	ε_t^w	ε_t^b	ε_t^f
(a) Labor Tax Model (τ^w)								
1	16.43	12.79	27.18	16.46	2.60	22.25	1.32	0.98
4	15.00	2.78	20.58	18.12	1.03	39.40	1.80	1.28
8	11.80	1.96	16.11	18.05	0.76	48.37	1.97	0.99
20	9.09	2.32	12.59	17.37	0.61	55.09	2.18	0.74
(b) Lump Sum Tax Model (T)								
1	17.52	14.24	28.22	12.57	2.22	23.82	1.42	0.00
4	15.76	3.53	22.61	12.90	0.74	42.49	1.98	0.00
8	12.24	2.12	18.70	12.52	0.49	51.91	2.02	0.00
20	9.69	1.59	15.89	12.10	0.38	58.27	2.09	0.00
(c) Capital Tax Model (τ^k)								
1	15.23	11.71	26.65	17.89	2.69	23.09	1.36	1.38
4	14.67	2.40	19.87	18.01	1.02	41.28	1.95	0.80
8	11.41	1.86	15.55	17.35	0.72	50.46	2.14	0.51
20	8.53	2.45	12.17	16.34	0.56	57.04	2.38	0.54
(d) Consumption Tax Model (τ^c)								
1	16.75	13.17	27.74	14.20	2.37	24.10	1.49	0.17
4	15.31	2.90	21.50	14.66	0.83	42.67	2.02	0.11
8	11.89	1.73	17.42	14.12	0.55	52.09	2.12	0.08
20	9.25	1.36	14.56	13.36	0.41	58.70	2.24	0.12

Note: Posterior mean of Variance Decomposition as obtained using the posterior distribution of the labor tax model.

that goes through the tax adjustment, directly in the case of the labor tax or the consumption tax model, indirectly through the wealth effect in the two other models. The exogenous spending shock, g_t accounts for 13% of output at horizon 1, but quickly vanishes after 1 year.

Panels (b) through (d) of the table report the variance decomposition of output in variants of the model where the labor tax is now held constant, while another tax is adjusting to satisfy the government budget constraint. The results indicate that as far as the contribution of each shock to the business cycle is concerned, the details of the implementation of fiscal stabilization policy through deficit does not matter. Letting either the labor tax, the consumption tax, the capital tax or the lump-sum component of the tax adjust does not affect neither qualitatively nor quantitatively the contribution of each shock to the dynamics of output. In other words, the policymaker is not in a position to affect the contribution of each shock to the business cycle by simply varying the tax instrument she uses while using a simple deficit (or total tax revenue) rule.[17]

2.5.2 Impulse responses

This section investigates the dynamics of the model in the aftermaths of a shock. Given that the preceding section pointed to technology, investment and the wage markup shocks as the main drivers of the business cycle, the analysis will be restricted to this set of shocks, to which the exogenous spending shock will be added. Accordingly, Figures 2.1–2.17 report the impulse responses following a temporary positive one standard deviation exogenous technology, investment efficiency, wage markup and government spending shock. As in the previous section, a first baseline impulse response function is obtained for the baseline labor tax model. Then the response to the shocks in the four variants of the model are considered.[18]

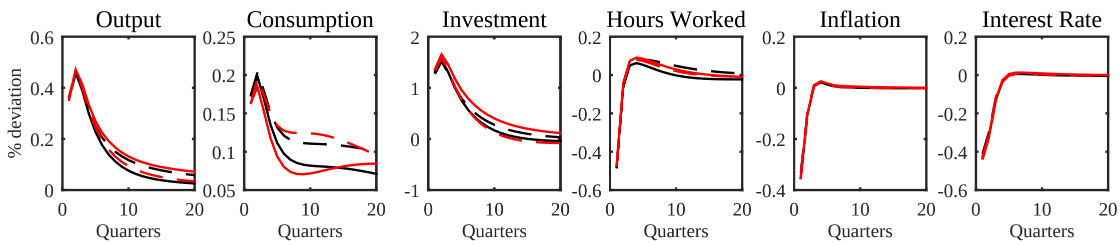
[17]Note however, that this does not mean that fiscal policy cannot by itself reshape the business cycle. Using an individual rule for each tax rate ought to have such an effect.

[18]As in the previous case, these variants are evaluated at the posterior distribution of the baseline model as a way to control the experiment and measure the very effect of varying the tax instrument.

Technology shock

Figures 2.1 and 2.2 report the impulse responses of selected macroeconomic aggregates and fiscal policy variables, respectively, to a temporary positive one standard deviation technology shock. The model confirms the standard intuition. Following the temporary increase in productivity, output, consumption and investment increase. Inflation drops, and given that monetary policy is conducted according to a Taylor rule so does the nominal interest rate. Hours worked fall due to the presence of *(i)* price stickiness (see Gali (1999)) and *(ii)* habit in consumption and investment adjustment costs (see Francis and Ramey (2005)). Finally because the tax base increases (output, consumption and investment increase), fiscal receipts increase and, accordingly, debt issuance recedes (Panels (a) and (b) of Figure 2.2). Note however that, in the baseline labor tax model, because hours worked are below their steady state on impact, the labor tax (Panel (c) of Figure 2.2) still has to mildly increase in the short run to make sure that the government budget constraint holds due to the initial decrease in public debt. But as of the second quarter the tax rate passes below its steady state.

Figure 2.1: Macroeconomic Aggregates (1 std.dev. Technology Shock)

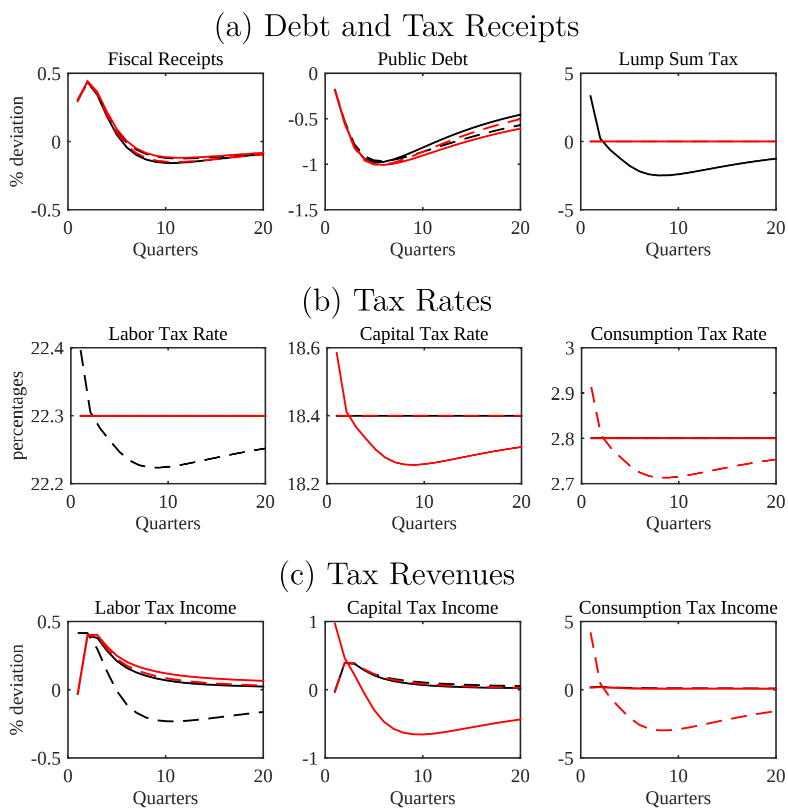


Baseline τ^w Model, T variant, τ^k variant, τ^c variant.

Note: Average of posterior distribution of IRFs.

When the labor tax is held constant at its steady state level and the adjustment is made by another tax, the results are qualitatively left unchanged. They however differ from a quantitative point of view. The most stabilizing tax, in terms of output, is the lump sum tax (dark plain line). This comes as no surprise as, by not distorting any of the decisions of the agents, this tax does not create any additional incentive at the margin to vary hours worked or investment more than what the standard wealth and substitution effects would prescribe. Therefore, as can be seen from Figure 2.1, hours worked and investment —and therefore output— are the less responsive in the lump sum tax variant.

Figure 2.2: Fiscal Policy (1 std.dev. Technology Shock)



- - - - Baseline τ^w Model, —— T variant, —— τ^k variant, - - - - τ^c variant.

Note: Average of posterior distribution of IRFs.

In contrast, the use of the capital tax (red plain line) to adjust the government budget constraint creates an intertemporal distortion that tends to destabilize output in comparison to the baseline labor tax model. On impact, just as in the labor tax case, the required increase in the tax revenues is accompanied by an increase in the capital tax on impact (See panel (b) of Figure 2.2). However, the increase in the tax base together with the persistence of the technology shock make the agents expect the capital tax rate to decrease. It will then be profitable to invest relatively more than in the labor tax case as of period 2, which, everything else equal, implies that consumption will be less than under labor tax adjustment. Consumption smoothing implies that, even though consumption rises on impact, it increases less than in the labor tax variant (See Figure 2.1), leaving more room for investment to increase. This also implies that the increase in consumption is less persistent. Likewise, leisure consumption increases less than in the labor tax case, implying that hours worked are more reactive.

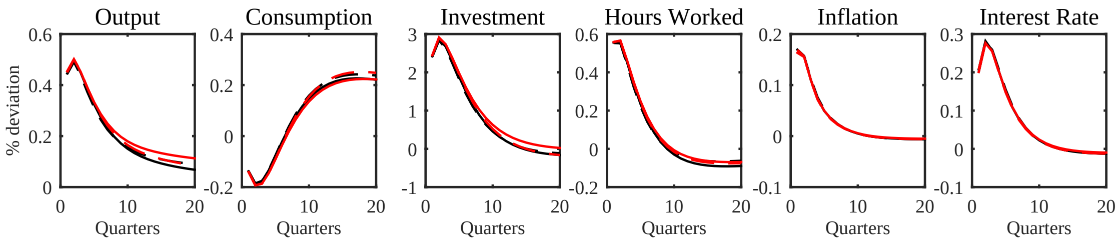
The use of the consumption tax also creates an intertemporal distortion. However, contrary to the capital tax, it leads to a relative stabilization of output compared to the labor tax case. Indeed, while, as in the case of the other tax, the consumption tax increases on impact, it decreases as of period 2, therefore creating an incentive to consume more (and for a more prolonged period of time). Hence, compared to the labor tax case, investment increases relatively less under a consumption tax adjustment. The same phenomenon occurs for hours worked. Output therefore reacts less. Note however that, given the low level of the consumption tax, the magnitude of the effect is lower than for the capital tax.

Interestingly, in all cases, inflation and the nominal interest rate are essentially unaffected by the fiscal developments.

Investment Efficiency Shock

Figures 2.18 and 2.19 report the impulse responses of selected macroeconomic aggregates and fiscal policy variables, respectively, to a temporary positive one standard deviation shock to investment efficiency. Just like in the case of a neutral technology shock, the impulse responses conform the intuition. An increase in the marginal efficiency of investment leads to an increase in the demand for investment, but creates negative comovement with consumption. The drop in consumption then lowers the marginal rate of substitution between consumption and leisure, which, given the real wage, requires hours —and therefore output— to increase. The increase in demand for investment creates upward pressure on the inflation rate and so on the nominal interest rate. Overall, fiscal receipts increase and debt

Figure 2.3: Macroeconomic Aggregates (1 std.dev. Investment Efficiency Shock)

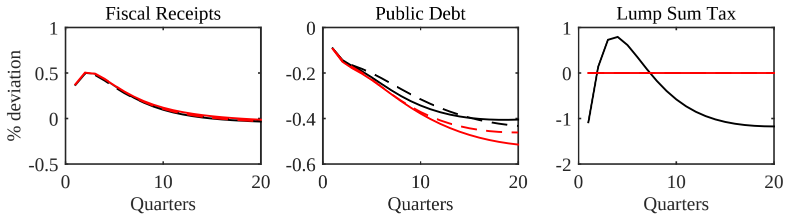


- - - - Baseline τ^w Model, —— T variant, —— τ^k variant, - - - - τ^c variant.

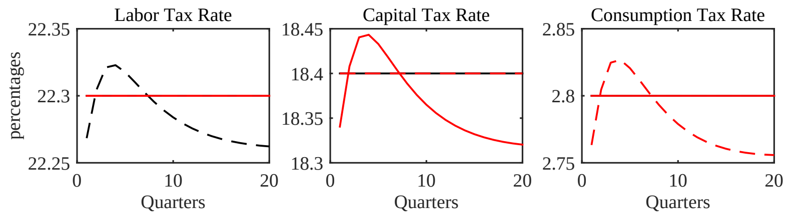
Note: Average of posterior distribution of IRFs.

Figure 2.4: Fiscal Policy (1 std.dev. Investment Efficiency Shock)

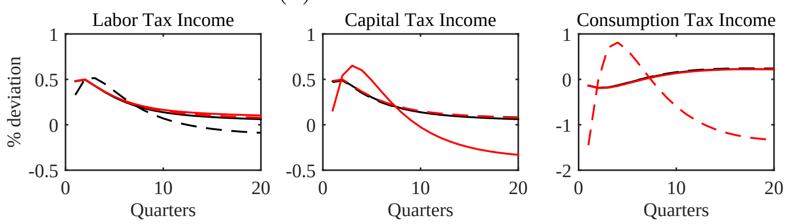
(a) Debt and Tax Receipts



(b) Tax Rates



(c) Tax Revenues



- - - - Baseline τ^w Model, —— T variant, —— τ^k variant, - - - - τ^c variant.

Note: Average of posterior distribution of IRFs.

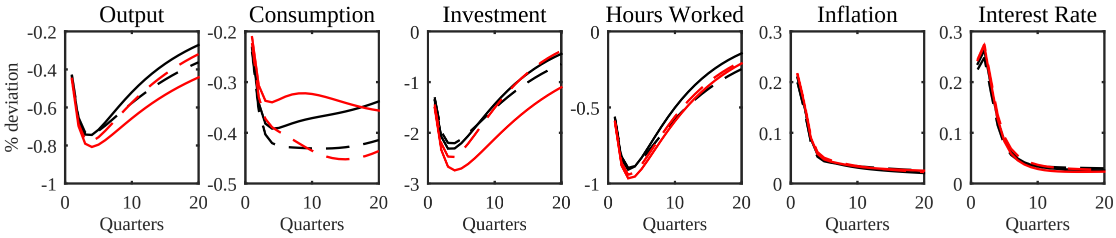
decreases. However, some heterogeneity in fiscal revenues emerge in face of an investment efficiency shock. The increase in capital and hours implies that capital tax and labor tax revenues increase. On the contrary, the lower consumption, by limiting the tax base, reduces the proceeds to VAT. Interestingly, the increase in the tax base permits a decrease in the tax rate on impact which fosters the initial response of hours worked in the baseline model. Note, however, that this reduction in the tax is tiny and leads to a very marginal effect on hours worked. The main reason for the limited amplitude of the tax rate adjustment is found in the evolution of the inflation rate. As previously, the inflation rate increases following the shock, which, *ceteris paribus*, reduces debt services. Given the increase in the tax base, the economy can even tolerate a very mild decrease in the tax rate and still ensure that the government budget constraint holds.

Holding the labor tax constant and adjusting the government budget constraint by another tax instrument leads to the same ranking, in terms of stabilization of output, as what was observed in the case of a neutral technology shock. The mechanisms leading to this ranking are essentially the same and hinge again on the type of distortion introduced by each tax. However, in the case of a shock to the marginal efficiency of investment, these effects are quantitatively negligible. The main reason for this result is found in the very mild reaction of each tax rate to the shock (less than 5 basis points in each case), which, in the presence of persistence and smoothing mechanisms like habit persistence or investment adjustment costs, are not enough to generate quantitatively sizable effects. Tax rates do not vary much in face of the investment efficiency shock.

Wage Markup Shock

Figures 2.22 and 2.23 report the impulse responses of selected macroeconomic aggregates and fiscal policy variables, respectively, to a temporary positive one standard deviation wage markup shock. The increase in the wage markup makes labor more expensive and depresses the demand for it, hours worked go down. Given that there is no concomitant technology shock, that capital is predetermined and that adjusting utilization is costly, output drops. The drop in hours reduces,

Figure 2.5: Macroeconomic Aggregates (1 std.dev. Wage Markup Shock)



Baseline τ^w Model, T variant, τ^k variant, τ^c variant.

Note: Average of posterior distribution of IRFs.

all things equal, the marginal efficiency of capital while the drop in output exerts a negative income effect that makes the agents both consume and invest less (therefore reinforcing the negative wealth effect). This lower demand in turn puts downward pressure on inflation and therefore on the interest rate. In other words, the wage markup shock is observationally equivalent to a neutral technology shock (although the mechanisms are different).

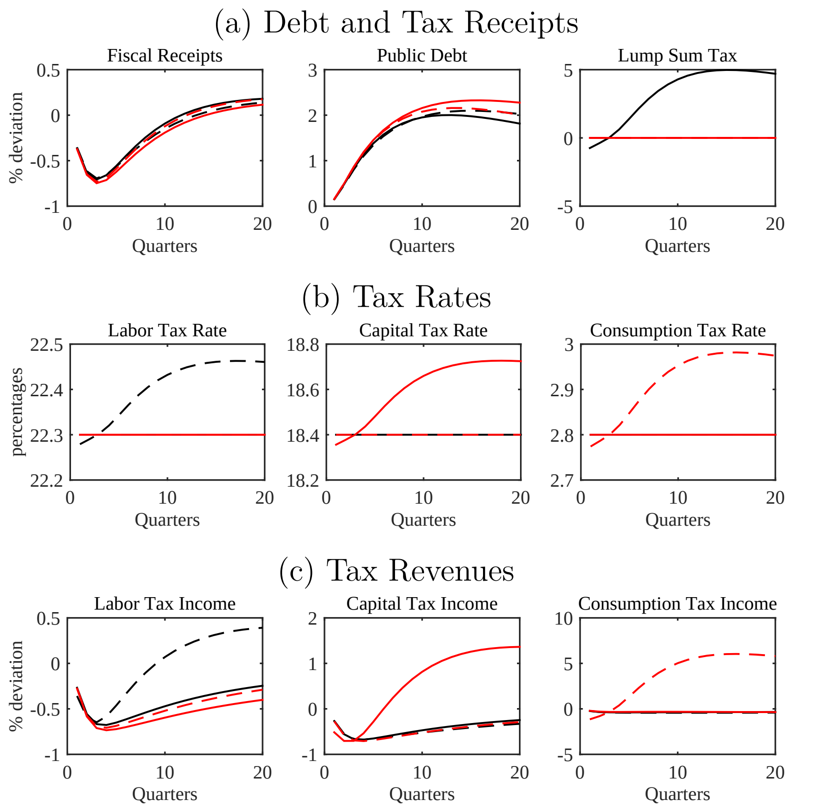
The drop in the tax base for both the labor, the capital and the consumption tax, together with the increase in the debt services associated with the lower inflation rate call for *(i)* an increase in debt issuance (see Panel (a) of Figure 2.23) and *(ii)* an increase in the tax rate. Note that initially the tax rate mildly decreases due to the initial debt issuance, but as of the second period the effects of the lower tax base and the increase charge of debt services call for an persistent increase in the labor tax rate (in the baseline model).

When alternative tax adjustments are put in place, the output stabilization ranking is the same as for the technology shock. Note however that the amplitude of the effects is stronger. The main reason for this is found in the key role played by the wage markup shock in this model. One way to think about it is to appeal to business cycle accounting arguments. The labor market equilibrium can be thought of as

$$MRS_t = \zeta_t MPL_t$$

where MRS_t denotes the marginal rate of substitution between consumption and

Figure 2.6: Fiscal Policy (1 std.dev. Wage Markup Shock)



Baseline τ^w Model, T variant, τ^k variant, τ^c variant.

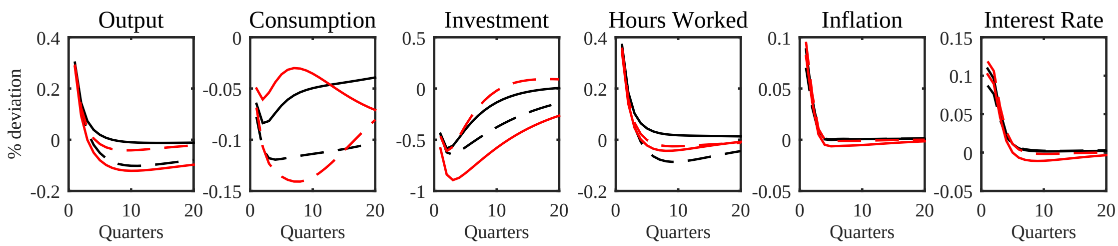
Note: Average of posterior distribution of IRFs.

leisure and MPL_t is the marginal product of labor. ζ_t is the labor wedge measure by Chari, Kehoe, and McGrattan (2007). In our setting the labor wedge is a combination of three different wedges: *(i)* a time varying markups related to the imperfect competition and nominal price rigidities on the good market, *(ii)* a time varying wage markup related to the presence of imperfect competition and nominal wage rigidities on the labor market, and *(iii)* time varying taxation. The wage markup shock affects directly the wage markups and the labor tax that are the main driver of the labor wedge, which has been found by Chari, Kehoe, and McGrattan (2007) to be key in shaping the business cycle. Alternative tax instrument will then have stronger implications on the dynamics than a technology shock.

Public Expenditures Shock

While the preceding sections were investigating the role of taxation in face of the main drivers of the business cycle, the present section investigates how it affects the financing of a shock to government spending (g_t). Figures 2.16 and 2.17 plot IRFs of macroeconomic aggregates and fiscal instruments to a temporary one standard deviation exogenous positive government expenditure shock.

Figure 2.7: Macroeconomic Aggregates (1 std.dev. Government Expenditures Shock)

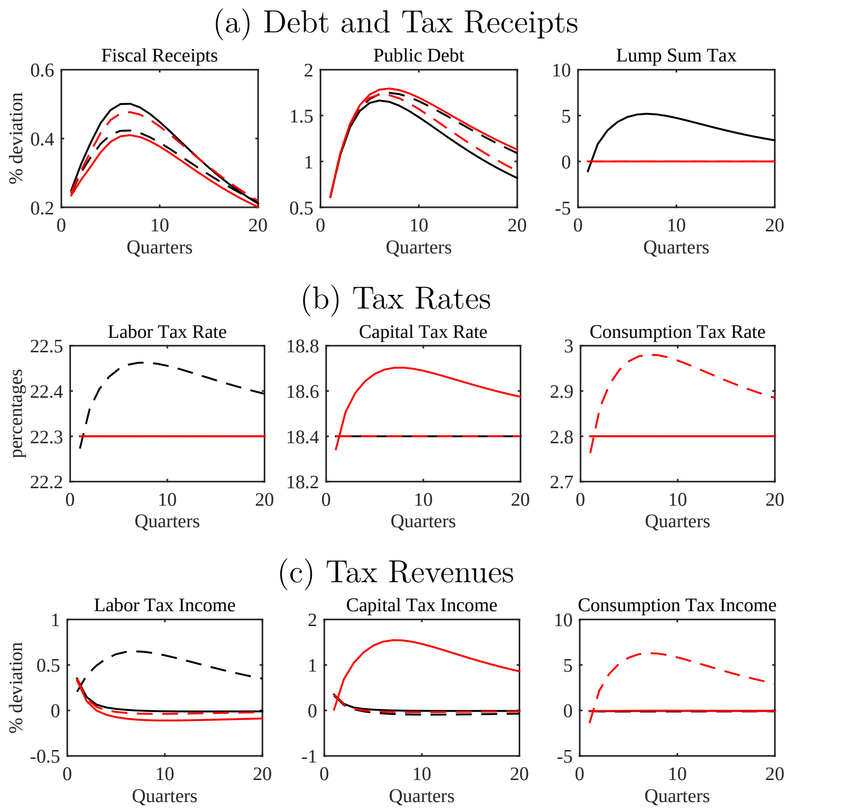


- - - - Baseline τ^w Model, —— T variant, —— τ^k variant, - - - - τ^c variant.

Note: Average of posterior distribution of IRFs.

The positive government expenditure shock also has standard implications in the baseline labor tax model. As the increase in government spending is persistent, households expect taxes to increase, therefore affecting negatively their permanent income. Consumption and investment are, accordingly, crowded out by public spendings. The drop in consumption affects the marginal rate of substitution between consumption an leisure and puts downward pressure on the real wage and leads to an increase in the labor demand. Hours worked increase. This increase in however partially mitigated by the increase in the tax rate that is required by the need to finance the stream of government expenditures. Note that part of the financing is achieved by issuing more debt (see Panel (a) of figure 2.16), which increases the charge of debt services and calls for another increase in the labor tax rate.

Figure 2.8: Fiscal Policy (1 std.dev. Government Expenditures Shock)



Baseline τ^w Model, T variant, τ^k variant, τ^c variant.

Note: Average of posterior distribution of IRFs.

Just like what was observed for the other shocks, the tax instrument used to balance the government budget constraint matters for the propagation of the shock. The stabilization effects of changes in the tax instrument are again similar to what obtained in the case of a technology shock, they are however magnified in the case of the government spending shock.[19] For instance, while, in the case of the lump sum tax and the consumption tax output converges monotonically to its steady state after the shock, variants with the labor and the capital tax eventually plunge the economy into a recession. In those cases the tax rates remain persistently above their steady state (see Panel (b) of Figure 2.17) as public debt rises and the tax base recedes. In the case of the baseline labor tax model, the increase in the tax rate increases, *ceteris paribus*, the wage rate increases (as the households that can re-optimize their wage in the current period want to be compensated for the tax increase) which implies that, eventually, the demand for labor drops, and so does output. In the case of the capital tax variant, the increase in the tax rate discourages investment further, which magnifies the crowding out effect of public spending. This exerts a negative demand effect on output. The same phenomenon occurs with the consumption tax, to a lesser extent though, given the consumption smoothing that prevents demand from dropping too much.

2.5.3 Tax Elasticities of Output

The preceding section has highlighted how different taxes can have different implications for the dynamics of output. This section offers an alternative perspective on this issue by calculating the tax elasticity of output conditional on each shock in each variant of the model. An attractive feature of this calculation is that it provides a measure of the potency of particular fiscal instruments for stabilizing output in face of a particular shock. It therefore supplements the preceding impulse response analysis. This elasticity is computed as the average total elasticity of output to the tax over a sample path. Denoting by $IRF_k^x(s)$ the k-periods ahead percentage deviation of variable x following a one standard deviation shock to forcing variable s, the elasticity conditional on s for an horizon

[19]The same obtains in the case of the fiscal revenue shock ε_t^f. The associated results are reported in the companion technical appendix.

H, $\mathscr{E}^y_\tau(s,H)$ is computed as

$$\mathscr{E}^y_\tau(s,H) = \frac{1}{H}\sum_{h=1}^{H}\frac{IRF_h^y(s)}{IRF_h^\tau(s)} \tag{2.39}$$

This quantity is computed for a sample of draws from the posterior distribution of the baseline labor tax model. Table 2.17 report the posterior mean of the elasticity for each shock in each variant of the model for a total horizon of 20 quarters.[20]

Table 2.5: Tax Elasticity of output (20 periods horizon)

Shock	Baseline τ^w	Lump-sum Tax	τ_k Model	τ_c Model
Technology	−0.406	−0.038	−0.200	−0.038
Government Expenditures	−0.227	−0.013	−0.115	−0.015
Investment Efficiency	−0.315	−0.028	−0.227	−0.036
Cost Push	−0.404	−0.042	−0.196	−0.038
Monetary Policy	−0.222	−0.012	−0.108	−0.013
Wage Markup	−0.818	−0.092	−0.357	−0.079
Preference	−0.401	−0.037	−0.187	−0.037
Discretionary Fiscal Policy	−0.094	0.000	−0.058	−0.006

All elasticities are negative pointing to the overall countercyclicality of fiscal policy: tax rates co-move negatively with output conditionally on each and every shock. Note however, that the tax revenues elasticity of output are positive (as the tax base is pro-cyclical), which is in line with previous findings by Blanchard and Perotti (2002a). Although the results exhibit a lot of variability in the size of elasticities both across shocks and across taxes, a systematic pattern emerges from the table. The labor tax adjustment model generates the highest tax elasticity of output, then the capital tax model, followed, somewhat identically, by the consumption and lump-sum tax models. This ranking applies for any shock and is

[20]The ranking reported in the table are robust to increasing the total horizon, only the level of the elasticity is affected. It is however worth noting that, from a quantitative point of view, the changes in the level are not large.

robust to changes in the total horizon considered in the calculation of the elasticity. In other words, adjusting the labor tax is the most potent way to stabilize output in face of any shock, with an elasticity ranging from -0.1 for the discretionary fiscal shock to -0.8 for the wage markup shock. Letting the capital tax rate proves less potent with a maximal elasticity of -0.36 in the case of the wage markup shock. Note that fiscal policy exhibits maximal efficacy to stabilize output fluctuations in the aftermaths of markup shocks (wage and cost push) and technology shocks (neutral and investment efficiency). This overall ranking supports our previous findings and actually highlights the well-known role of the labor markets and capital accumulation in the propagation of shocks in this class of models. The presence of nominal rigidities affecting both prices and wages creates a form of real wage rigidity that magnifies the role of labor fluctuations in shaping the business cycle. Adjustments in the labor tax rate, by affecting the wage selected by the households that can reset it, therefore plays a key role for output stabilization.

2.5.4 Second–order moments

The preceding results suggested that the exact implementation of the fiscal rule (deficit rule) might matter for the shape and magnitude of the response of macroeconomic variables to the various shocks hitting the economy. While that information was conditional, this section investigates the implications of various tax implementations of the rule for unconditional moments. Tables 2.20 and 2.7 report HP-filtered ($\lambda = 1600$) second-order moments –the standard deviations and correlations with output– of the main macroeconomic variables for all four variants of models evaluated at the posterior mode of the baseline labor tax model.

The inspection of the volatilities across models reveals that, with the exception of the lump-sum tax model, the baseline labor tax model achieves the highest level of output stabilization. This essentially confirms the conditional results obtained in the IRF analysis. However, the effects are quantitatively small. For instance the volatility of output in the baseline model is 1.6% and only raises to 1.7% in the worst case (τ^k model). Differences are more pronounced for investment volatility and to some extent for hours worked. However, differences remain marginal. The same result holds for co-movements. This is an important result as it indicates that, as soon as the government uses a deficit rule, the exact details of its implementation have very little quantitative consequences for the positive properties of the economy. This stands in contrast to models that specify a rule for each tax rate in the system (see for example Leeper, Plante, and Traum (2010)). In such models, altering one particular tax rule can have sizable consequences for the business cycle properties of the model — both in terms of volatility or co-movements. However, in those models the rule –and hence the stabilization properties– and the implementation are mixed and cannot be separated. One important contribution of this paper is to disentangle the stabilization properties (the rule) from the implementation of the rule.

Table 2.6: Second Order Moments (Main aggregates)

Var.	Baseline τ^w	Lump-sum Tax	τ_k Model	τ_c Model
Volatilities				
y	1.60	1.57	1.67	1.62
c	1.05	1.01	0.98	1.08
i	6.90	6.98	7.45	7.23
h	1.89	1.85	1.93	1.91
π	0.71	0.72	0.72	0.73
R	0.91	0.93	0.94	0.95
Correlation with Output				
c	0.25	0.19	0.15	0.20
i	0.85	0.86	0.87	0.85
h	0.84	0.84	0.85	0.85
π	-0.03	-0.03	-0.02	-0.03
R	-0.17	-0.17	-0.16	-0.17

Note: Average of the posterior distribution of HP filtered moments ($\lambda = 1600$)

Does this however mean that implementation does not matter? The answer to this question is clearly negative. Table 2.7 reports the volatility and the co-movements of the fiscal variables in the model. It then appears that the baseline labor tax model allows to achieve output stabilization without requiring too much volatility in tax revenues and public debt.

Table 2.7: Second Order Moments (Fiscal Variables)

Var.	Baseline τ^w	Lump-sum Tax	τ_k Model	τ_c Model
Volatilities				
F	2.41	2.62	2.48	2.60
D	3.70	3.93	3.91	4.02
τ_w	3.22	–	–	–
T	–	24.20	–	–
τ_k	–	–	7.36	–
τ_c	–	–	–	29.46
Correlation with Output				
F	0.54	0.59	0.55	0.57
D	-0.32	-0.28	-0.36	-0.32
τ_w	-0.24	–	–	–
T	–	-0.09	–	–
τ_k	–	–	-0.24	–
τ_c	–	–	–	-0.14

Note: Average of the posterior distribution of HP filtered moments ($\lambda = 1600$).

For instance, while the labor tax model generates a volatility of tax revenues (resp. public debt) of 2.4% (resp. 3.7%), the model in which the consumption tax adjusts yields higher a volatility of 2.6% (resp. 4%). This is due to the lower volatility of the labor tax, 3.2%, relative to that of the consumption tax, 29.5%. In other words, and it comes as no surprise, the positive properties of the tax system are strongly affected by the implementation. While, as the preceding analysis showed, this is innocuous from a positive point of view, it ought to have strong implications for a normative analysis. Although such an analysis is beyond the scope of this paper, two points are worth mentioning. The presence of a time varying labor (or capital or consumption) tax adds an additional time varying distortion to the model beyond the price and wage markups, which can adds to the welfare cost of fluctuations for the agents. Second, in world where the central bank takes fiscal policy as given, the presence of a time varying tax rate can bring back an inflation output stabilization trade-off that would affect the shape of optimal monetary policy (see for instance Collard and Dellas (2006)).

2.6 Sensitivity analysis

The preceding results suggested that implementing the tax rule through adjustments in the labor tax performs best in terms of stabilization. This section assesses the robustness of these findings against *(i)* alternative monetary policies —*i.e.* parametrization of the Taylor rule, *(ii)* alternative fiscal rules, and *(iii)* alternative specification of nominal rigidities, in particular those that abstract from the nominal wage rigidity.

2.6.1 Monetary Policy

The present model is an attempt at modeling the interactions between monetary and fiscal policies. It is commonly thought among policy makers that monetary policy is responsible for inflation stabilization while fiscal policy is in charge of output and debt stabilization. These differing objectives can be a source of conflict, and monetary policy may actually undo what fiscal policy tries to achieve (and vice versa). Consider, for example, a central bank that is solely concerned with inflation stabilization and implicitly leaves output stabilization to the fiscal authority.[21] The

[21]Note however that in the standard New Keynesian model a central bank that would achieve full price stability would also achieve full output stability, which leaves the fiscal authority in charge of controlling the debt level. We will study this case later on.

fiscal authority, if it is also required to ensure public debt sustainability, may be less effective in terms of output stabilization as the fiscal instrument —*.e.* tax rate— then faces the opposing demands from output and debt stabilization. Let us consider the case of a negative technology shock that reduces output and increases inflation. A central bank that follows a Taylor rule increases the nominal interest rate. This, in turn, makes public debt servicing costlier[22] and therefore calls for a tax rise which further depresses output and deepens the recession. It follows that the interaction between monetary and fiscal policy –and the resulting trade off between inflation and output stabilization– have significant implications both for financing of public debt and output stability. This section investigates this issue and reports the output elasticities to taxes when the central bank's response to the inflation gap, κ_π, and to the output gap, κ_y, are varied (see Equation 2.24). It is assumed that the central bank follows either

(i) full price stabilization ($\kappa_\pi = \infty$), or

(ii) countercyclical ($\kappa_y = 0.5$), or finally

(iii) a-cyclical monetary policy ($\kappa_y = 0$).

The output responses to tax rate changes are computed individually for each of the eight shocks that hit the economy. The first column of Table 2.8 reports the output elasticity based on the mean posterior of monetary policy parameters as estimated for the benchmark labor tax model (see Section 2.4.2). The next column shows the output elasticity estimates following various shocks when the central bank achieves full price stability, while the remaining two columns show what happens when, under partial price stabilization, its focus on the output gap is varied.

In the standard New-Keynesian model, and under full price stabilization policy, the central bank fully closes the inflation gap and, by so doing, sets markups constant and closes the gap between actual and natural output.[23] In such an equilibrium, the nominal interest rate is insensitive to the shocks hitting the

[22]The Taylor principle implies that the increase in the nominal rate also corresponds to an increase in the real rate.

[23]Here, the natural output refers to the level of output reached in the flexible price allocation.

economy—to the notable exception of a monetary policy shock. This is not the case in this model. The reason is that fiscal policy introduces an additional time varying wedge in the output gap: time varying tax rates. In such a setting variations in the tax rate are different in the flexible price allocation and in the sticky price allocation, and monetary policy is not sufficient to shut this channel down. This has multiple implications. A first implication is that the nominal interest rate still varies with the output gap, such that debt services are affected by movements in the interest rate. A second implication is that variations in the tax rate ought to counter the effects of monetary policy, and this may introduce a trade off between price and output stabilization.[24] To see this let us consider the case of a technology shock. In the benchmark model a positive technology shock implies a decrease in inflation which, given that nominal wages are sticky, yields an increase in the real wage which mitigates the increase in the demand for labor. By fully stabilizing inflation, the central bank shuts this mechanism down and the real wage does not move (or very little under the Calvo scheme), therefore firms are willing to increase their labor relatively more than in the benchmark Taylor rule, therefore fostering the volatility of labor and hence output. Not surprisingly then, fiscal policy under full price stabilization achieves the lowest level of output stabilization —as confirmed by the standard deviation of output unconditional of shocks hitting the economy —the output volatility increases from 1.60% as in the baseline case to 1.75%. This however does not undermine the potency of fiscal policy. Since the monetary policy still closes, partially, the gap between actual output and its natural level, some of this correction is left up to the fiscal policy to make. The results in Table 2.8 show that the output elasticity to taxes increases (decreases) in magnitude for each shock with the exception of technology and wage markup shocks —increasing fiscal policy potency to stabilize output. Additionally, another noteworthy results is that the output elasticity turns positive for the investment efficiency shock —with a coefficient of 0.133 compared to -0.315 for the benchmark labor tax model— implying that the labor tax rate co-moves positively with output

[24] This is reminiscent of Collard and Dellas (2006) who obtain a similar trade-off in a model where the level of the income tax rate is indexed on output.

conditional on the investment shock.

Table 2.8: Tax Elasticities of output (20 periods horizon)

	Baseline	Inflation	Output	
Shock	τ^w Model	$\kappa_\pi = \infty$	$\kappa_y = 0$	$\kappa_y = 0.5$
	Labor Tax Model			
Technology	-0.406	-0.507	-0.401	-0.447
Government Expenditures	-0.227	-0.165	-0.227	-0.231
Investment Efficiency	-0.315	0.133	-0.265	-0.407
Cost Push	-0.404	-0.343	-0.402	-0.437
Monetary Policy	-0.222	-0.193	-0.222	-0.220
Wage Markup	-0.818	-1.144	-0.750	-0.626
Preference	-0.401	-0.356	-0.372	-0.376
Discretionary Fiscal Policy	-0.094	-0.099	-0.095	-0.095
Std(y)	1.601	1.747	1.607	1.541

Note: Average of Posterior Distribution of Elasticities.

Let us now consider the case of a central bank which (partially) stabilizes prices and has no concern for the output gap ($\kappa_y = 0$). The a-cyclical monetary policy implies that no systematic relationship between the nominal interest and output fluctuations exists —widening or narrowing of the output gap are neither reinforced nor stabilized by the nominal interest rate. An implication of this is that output stabilization is left solely up to the fiscal authorities. For example, higher inflation, following a positive wage markup shock, calls for an increases in the nominal interest rate. This, in turn, makes debt services costlier and leads to an increase in taxes. But output stabilization demands lower taxes. There appears a conflict between output and debt stabilization. In other words, fiscal policy potency is reduced, although marginally, under a-cyclical monetary policy. The marginally higher output volatility is confirmed by standard deviation of output —it increases to 1.61% from 1.6% in the benchmark labor tax model. The tax elasticity of output under a-cyclical policy is relatively robust for any shocks with the exception of an investment efficiency shock for which fiscal policy is less potent —it increases from -0.315 in the benchmark labor tax model to -0.265.

As the central bank's concern for stabilization of the output gap rises, positive spillovers from monetary to fiscal policy grow—the fiscal authority needs less to worry about stabilizing the output and is thus freer to focus on controlling debt stabilization. In other words, the fiscal policy potency is improved for all the shocks —with the sole exception of a wage markup shock— as confirmed by higher output elasticities (see fourth column in Table 2.8). Fiscal policy becomes most potent in the face of an investment shock with an output elasticity increasing from -0.315 in the benchmark labor model to -0.407.

2.6.2 Fiscal Rule

Fiscal policy in this paper is modeled by a simple fiscal rule (deficit rule) which serves two main purposes: *(i)* to achieve output stability and *(ii)* to discipline the evolution of real debt and aid its sustainability. These fiscal pursuits might conflict over the business cycle and as such reduce the potency of fiscal policy. For example, in the face of positive wage markup shock, the resulting output loss demands a tax cut to foster growth but the ensuing increase in debt issuance demands higher taxes. The resulting trade off between output and debt stabilization places constraints on the fiscal policy and restricts its potency. This section investigates this issue by reporting the labor tax elasticities of output computed by varying fiscal authorities' responses to output and debt fluctuations —γ_y and γ_d in Equation (2.29), respectively. The response to output fluctuations, γ_y, is varied from 0.5 to 1, hence shifting the main objective of fiscal policy towards output stabilization. Then, the response to changes in debt, γ_d, is varied as a way to evaluate the role of shifting the objective towards more debt discipline, as the recent crisis has brought back to most governments in the world.

Table 2.9 reports the output elasticities to the labor tax for each shock and for each imposed parametrization. For comparison purposes, the first column of the table reproduces the output elasticities in the benchmark labor tax model based on the posterior distribution of fiscal policy parameters. Although the results exhibit a lot of variations in the size of elasticities both across shocks and across the different parameterization of the fiscal rule, a systematic pattern emerges from the results. The largest variation in the tax elasticity of output, across all parameterizations, is obtained in the case of investment efficiency, wage markup and technology shocks —the shocks identified in the benchmark analysis as major contributers to the business cycle fluctuations. Fiscal policy becomes most potent in the face of investment and wage markup shocks for lower γ_y. The trade-off between output and debt stabilization is reduced once the fiscal authorities concern themselves less with a pursuit of output stability. But as fiscal authorities move towards greater output stabilization (see third column of Table 2.9) —where any deviations of output from its steady state level leads to a one-for-one increase in tax revenue achieved by a raise in the tax rate —the effectiveness of fiscal policy is improved for the government shock but lowered for technology and wage markup shocks. Furthermore, in the face of investment shock, the elasticity turns positive which implies that labor tax rate co-moves positively with output conditional on the investment shock.

Unsurprisingly, fiscal policy that pursues greater output stabilization brings about lower output volatility —1.55 relative to 1.6 in the benchmark labor tax model. Note however that the volatility gains are quantitatively small.

Consider now the case where the fiscal authorities have higher concern for debt stabilization ($\gamma_d = 1$).[25] This shift in the concerns of fiscal authorities reinforces the trade-off between disciplining the evolution of debt and stabilizing output. To understand this trade-off let us consider the case of a positive technology shock. As previously explained, this shock leads to a decrease in public debt and hence in the tax rate (in particular the labor tax rate) which, by a substitution effect, increases equilibrium hours, therefore reinforcing the initial effect of the shock. Labor, and henceforth output, volatility increases. Debt discipline therefore comes at the cost of greater output volatility. In this setting it is then not surprising that output volatility increases with the greater concern for debt stabilization (1.6 in

[25]Note that the concern for output is still maintained, but appears to be relatively smaller.

Table 2.9: Tax Elasticities of output (20 periods horizon)

	Baseline	Output		Debt	
Shock	τ^w model	$\gamma_y = 0.50$	$\gamma_y = 1.00$	$\gamma_d = 0.1$	$\gamma_d = 1$
		Labor Tax Model			
Technology	-0.406	-0.497	-0.123	-0.381	-0.460
Government	-0.227	-0.132	-0.455	-0.187	-0.342
Investment	-0.315	-1.198	0.176	-0.219	-0.943
Cost Push	-0.404	-0.382	-0.423	-0.466	-0.382
Monetary Pol.	-0.222	-0.211	-0.229	-0.232	-0.366
Wage Markup	-0.818	-1.101	-0.176	-0.676	-0.653
Preference	-0.401	-0.569	-0.363	-0.447	-0.421
Disc. Fiscal Pol.	-0.094	-0.099	-0.095	-0.093	-0.144
Std(y)	1.60	1.70	1.55	1.58	1.80

Note: Average of Posterior Distribution of Elasticities.

the benchmark case, versus 1.8 for $\gamma_d = 1$). Does this reduce the potency of fiscal stabilization? Table 2.9 indicates that, as the debt stabilization concern increases, the output elasticities for each shock rises —with the exception of cost push and wage markup shocks— suggesting an improved potency of fiscal policy. The largest increase in the effectiveness of fiscal policy is in the face of investment shocks —by more than a threefold increase in the output elasticity.

2.6.3 Endogenous Government Spending Rule

So far, government spendings have been held constant over time, $g_t = \bar{g}\ \forall\ t = 0, \ldots, \infty$.[26] However, government spending are often used as "*automatic stabilizers*" (Blanchard (1984)) to stabilize output. This section investigates the implications of endogenous government spending for the effectiveness of tax policy. For example, the previous section has shown that a positive wage markup shock depresses output and therefore calls for a tax cut. But the government might increase its spending, therefore counting on a multiplier effect, to foster the recovery which in turn might either mitigate or worsen the ensuing trade off between output and debt stabilization. To investigate this issue, this section considers the case where government expenditure follows the simple rule

$$\log(g_t) = \rho_g \log g_{t-1} + \zeta_y \log\left(\frac{y_t}{\bar{y}}\right) + \varepsilon_t^g \tag{2.40}$$

where $\rho_g \in (0, 1)$ and $\zeta_y < 0$. The rule indicates that the government follows a countercyclical policy and hence raises public expenditures whenever output falls below its steady state. Finally, it is assumed that the government spending shocks ε_t^g follow a first–order autoregressive process of order 1

$$\log \varepsilon_t^g = \rho_g \log \varepsilon_{t-1}^g + \epsilon_t^g, \tag{2.41}$$

where $|\rho_g| \in (0, 1)$ and $\epsilon_t^g \sim N(0, \sigma_r)$.

Table 2.10 compares the variance decomposition of output in the baseline model with constant government spending and in a variant with the exogenous spending

[26] The government spending is set at its steady state value of $\bar{g} = 0.2\bar{y}$

rule. On the one hand, the contribution of technology and wage markup shocks to output volatility reduces –while technology shock previously explained around 16%, at the impact, now it barely accounts for 5.6% of output variations. On the other hand, preference and cost push shocks all become more important contributer to the business cycle. This is especially pronounced in the face of preference shocks whose contribution to output volatility significantly increases both on impact and at higher horizons –it accounted for 2.2% in the baseline case and now to 60% in the output volatility at the 5 year horizon.

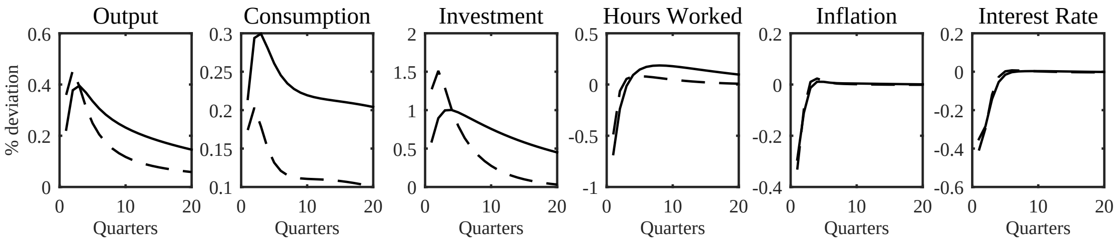
Table 2.10: Variance Decomposition of output

	a_t	g_t	ε_t^i	ε_t^π	ε_t^R	ε_t^w	ε_t^b	ε_t^f
Labor Tax Model: constant government spending								
1	16.43	12.79	27.18	16.46	2.60	22.25	1.32	0.98
4	15.00	2.78	20.58	18.12	1.03	39.40	1.80	1.28
8	11.80	1.96	16.11	18.05	0.76	48.37	1.97	0.99
20	9.09	2.32	12.59	17.37	0.61	55.09	2.18	0.74
Labor Tax Model: government spending rule								
1	5.50	11.75	26.06	24.50	2.54	9.40	19.31	0.94
4	6.68	2.11	24.41	22.65	1.19	10.70	31.49	0.76
8	5.43	1.30	20.97	20.22	0.91	8.34	42.43	0.42
20	3.68	1.23	13.96	15.45	0.63	5.29	59.51	0.24

Note: Variance Decomposition are evaluated at the posterior mean of the distribution.

In order to provide a better understanding of the role of endogenous government spending in shaping macroeconomic dynamics, Figures 2.9 and 2.27 compare the impulse responses of selected macroeconomic aggregates and fiscal policy variables to a one standard deviation technology shock both with exogenous (dashed line) and endogenous (unbroken line) government spending (Equation 2.40). As previously explained, following the temporary increase in productivity, output, consumption

Figure 2.9: Macroeconomic Aggregates: endogenous government spending (1 std.dev. Technology Shock)



- - - - Baseline τ^w Model, ——— endogenous g_t variant

Note: Average of posterior distribution of IRFs.

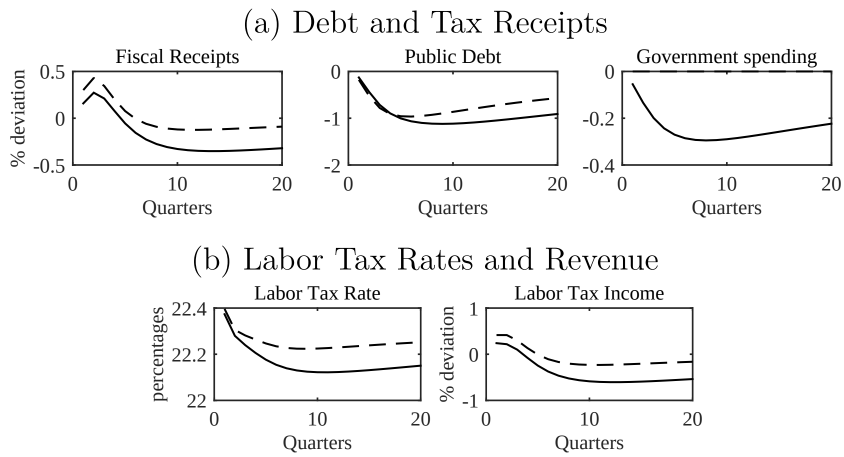
and investment increase. A government that has a concern for output stabilization then sees output rising above its steady state level and, following rule (2.40), contracts its expenditures. This policy eases then a pressure on public finances and, accordingly, debt issuance recedes (Panels (a) and (b) of Figure 2.27). Lowering in the public debt also sees its servicing fall which is then reflected in the lower fiscal pressure (both the tax rate and fiscal revenue decrease).

Fiscal policy with an active expenditure rule, however, achieves lower level of output stabilization —as confirmed by the standard deviation of output unconditional of shocks hitting the economy —the output volatility increases from 1.60% as in the baseline case to 2.07%. This increase reflects the higher persistence of the response of output tot he shocks. This however does not undermine the potency of fiscal policy. Table 2.11 indicates that the output elasticities for each shock rises —with the exception of markup shocks— suggesting an improved potency of fiscal policy. The largest increase in effectiveness of fiscal policy is in the face of investment shock —by more than a threefold increase in the output elasticity.

2.6.4 Absence of Nominal Wage Rigidity

The preceding sections assumed nominal rigidities for both prices and wages, and hence some real wage rigidities which magnify the role of labor fluctuations in

Figure 2.10: Fiscal Policy: endogenous government spending (1 std.dev. Technology Shock)



- - - - Baseline τ^w Model, —— endogenous g_t variant

Note: Average of posterior distribution of IRFs.

Table 2.11: Output Elasticity to Taxes: Varying government spending

Shock	Benchmark τ^w model	Endogenous g_t
Technology	-0.406	-0.460
Government Expenditures	-0.227	-0.276
Investment Efficiency	-0.315	-0.995
Cost Push	-0.404	-0.370
Monetary Policy	-0.222	-0.262
Wage Markup	-0.818	-0.357
Preference	-0.401	-1.044
Discretionary Fiscal Policy	-0.094	-0.160
Std(y)	1.601	2.071

Note: Elasticities are evaluated at the posterior mean of the distribution.

shaping the business cycle. Adjustments in the labor tax rate, by affecting the wage selected by the households when she can reset it, therefore plays a key role for output stabilization. To investigate this issue, this section assesses the robustness of our previous findings to relaxing the nominal wage rigidity.

Table 2.21 compares the variance decomposition of output in the baseline model and in a variant where only prices are sluggish. Eliminating the nominal wage rigidity affects marginally the variance decomposition of output. The contribution of the investment efficiency shock reduces at all horizon, which is in line with previous findings in the literature pointing to the role of nominal wage rigidities for the importance of investment shocks (see, among others, Justiniano, Primiceri, and Tambalotti (2010)). On the contrary, the technology and the price markup shocks become bigger contributors to output volatility.

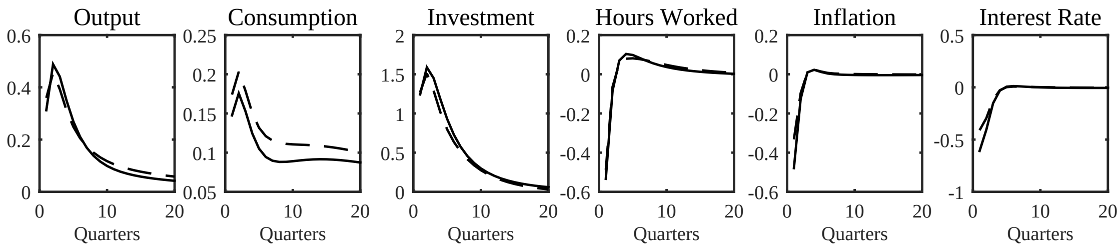
Table 2.12: Variance Decomposition of output: Nominal Price Rigidities

	a_t	g_t	ε_t^i	ε_t^p	ε_t^R	ε_t^w	ε_t^b	ε_t^f
Labor Tax Model: Benchmark								
1	16.43	12.79	27.18	16.46	2.60	22.25	1.32	0.98
4	15.00	2.78	20.58	18.12	1.03	39.40	1.80	1.28
8	11.80	1.96	16.11	18.05	0.76	48.37	1.97	0.99
20	9.09	2.32	12.59	17.37	0.61	55.09	2.18	0.74
Labor Tax Model: Absent Nominal Wage Rigidity								
1	19.96	19.70	12.55	23.33	2.13	20.53	0.61	1.18
4	24.14	4.10	7.09	24.23	0.65	37.02	1.28	1.50
8	19.27	3.03	5.11	23.56	0.47	46.13	1.29	1.14
20	14.79	3.11	3.91	21.18	0.38	54.44	1.30	0.88

Note: Variance Decomposition are evaluated at the posterior mean of the distribution.

Figures 2.11 and 2.12 compare the impulse responses of selected macroeconomic aggregates and fiscal policy variables to a one standard deviation technology shock, in an economy featuring both nominal price and wage rigidities and those obtained in the flexible nominal wage economy. Exclusion of nominal wage rigidities does not

Figure 2.11: Macroeconomic Aggregates: Removing Nominal Wage Rigidities (1 std.dev. Technology Shock)



- - - - Baseline τ^w Model, —— nominal price variant

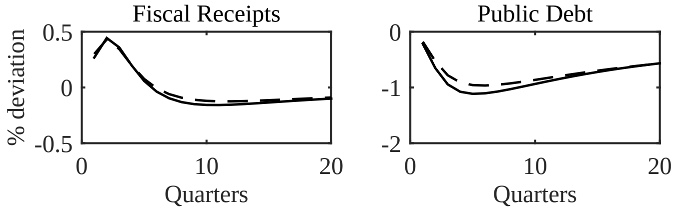
Note: Average of posterior distribution of IRFs.

affect either the dynamics or the magnitude of the response of aggregate and fiscal variables. Only aggregate consumption is marginally affected. It is only in the face of shocks that affect the intertemporal substitution between leisure and consumption and, thus, the real wage –in particular, in the face of preference, fiscal and wage markup shocks– that the endogenous responses of macroeconomic aggregates to a fiscal implementation are affected (see Technical Appendix). Furthermore, removal of nominal wage rigidities reduces inflation persistence and therefore affects the propagation of monetary policy shocks (see Gali and Gertler (1999) and Christiano, Eichenbaum, and Evans (2005b)).

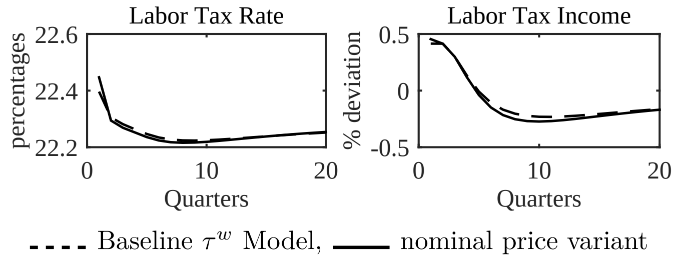
Unsurprisingly, absence of nominal wage rigidity achieves bigger output stabilization –the output volatility falls from 1.60% in the baseline case to 1.36%. Fiscal policy potency is only marginally affected by exclusion of nominal wage rigidities as evident by the output elasticities to taxes. The largest change in output elasticity is in the face of investment shock which turns positive —with a coefficient of 0.192 compared to -0.315 for the benchmark labor tax model— implying that the labor tax rate now co-moves positively with output conditional on the investment shock.

Figure 2.12: Fiscal Policy: Removing Nominal Wage Rigidities (1 std.dev. Technology Shock)

(a) Debt and Tax Receipts



(b) Labor Tax Rates and Revenue



Note: Average of posterior distribution of IRFs.

2.7 Conclusion

This paper evaluates the potency and efficiency of individual fiscal instruments, typically used by governments for public debt financing, in stabilizing the business cycle. To this end, it estimates the DSGE model that incorporates a fiscal policy rule and the non-trivial debt dynamics. Contrary to previous papers in the literature, the fiscal rule employed in the model does not use a particular instrument but rather relies on total tax revenues to stabilize the economy. When government spending are held constant, as is the case in the first part of this paper, this rule essentially corresponds to a deficit rule. This makes it possible to investigate the important question of the implementation of the deficit rule, more precisely it permits to evaluate the effects of using alternative tax instruments to implement a particular deficit and compare their relative performance in terms of output stabilization.

The results indicate that fiscal policy implementation achieved through

Table 2.13: Elasticities to Labor Taxes

Shock	benchmark	nominal prices
	Output	
Technology	-0.406	-0.467
Government Expenditures	-0.227	-0.169
Investment Efficiency	-0.315	0.192
Cost Push	-0.404	-0.374
Monetary Policy	-0.222	-0.155
Wage Markup	-0.818	-0.934
Preference	-0.401	-0.379
Discretionary Fiscal Policy	-0.094	-0.091
Std(y)	1.601	1.359

Note: Elasticities are evaluated at the posterior mean of the distribution.

adjustment in labor tax attains the highest level of output stabilization. However, the effects are quantitatively small indicating that as soon as the government uses a deficit rule, the exact details of its implementation have very little quantitative consequences for the positive properties of the economy. This is contrary to models that specify a rule for each individual tax rate (for example Leeper, Plante, and Traum (2010)) where altering one particular tax rate (and hence one of the tax rules) can have sizable consequences for the business cycle properties of the model –both in terms of volatility or co-movements. However, in those models, the rules are relatively difficult to compare as they differ significantly from one fiscal instrument to another. Furthermore, they do not separate the objective, output stabilization, from implementation. One contribution of the paper was to show that once the objective is set, its exact implementation does not really matter from a positive point of view.

Quantitatively small effects of fiscal policy, as found in this paper, do not however imply that the fiscal implementation does not matter. In fact, we find that the baseline labor tax model achieves output stabilization without requiring too much volatility in tax revenues and public debt. In other words, the positive properties of the tax system are strongly affected by the implementation. Even though we find that this is innocuous from a positive point of view, it ought to have strong implications for a normative analysis. Although such an analysis is beyond the scope of this paper, two points are worth mentioning. The presence of a time varying labor (or capital or consumption) tax adds an additional time varying distortion in the model beyond the price and wage markups, which can add to the welfare cost of fluctuations for the agents. Second, in world where the central bank takes fiscal policy as given, the presence of a time varying tax rate can bring back an inflation output stabilization trade-off that would affect the shape of optimal monetary policy. This normative analysis is left for further research.

APPENDIX

2.A Data

The data is from the Saint–Louis Federal Reserve Economic Database. The sample ranges from 1960Q1 to 2007Q4. To avoid dealing with the financial great recession, which the present model is not designed to deal with, the sample was stopped at the end of 2007. All quantities are expressed in real terms –deflated by the implicit GDP deflator (GDPDEF)– and also in per capita terms –deflated by civilian non-institutional population (CNP16OV). Since the latter series is available on monthly basis, the value reported for the last month of each quarter was taken as the quarterly observation. Similarly, as the effective federal funds rate is only available on monthly basis, the average over quarter is considered. Table 2.14 and 2.15 summarize the information about the data.

Table 2.14: Data Description

Mnemonic	Description	Units
`CBI`	Change in Private Inventories	Billions of Dollars
`CNP16OV`	Civilian Non–institutional Population	Thousands of Persons
`COMPNFB`	Nonfarm Business Sector: Compensation Per Hour	Index 2005=100
`FEDFUNDS`	Effective Federal Funds Rate	Percent
`FPI`	Fixed Private Investment	Billions of Dollars
`GDP`	Gross Domestic Product, 1 Decimal	Billions of Dollars
`GDPDEF`	Gross Domestic Product: Implicit Price Deflator	Index 2005=100
`GRECPT`	Government Current Receipts	Billions of Dollars
`HOANBS`	Nonfarm Business Sector: Hours of All Persons	Index 2005=100
`PCDG`	Personal Consumption Expenditures: Durable Goods	Billions of Dollars
`PCESV`	Personal Consumption Expenditures: Services	Billions of Dollars
`PCND`	Personal Consumption Expenditures: Nondurable Goods	Billions of Dollars

Source of original data: Federal Reserve Economic Database (FRED), Federal Reserve Bank of St. Louis

Table 2.15: Data Description

Data	Formula
Consumption	C=log((PCND+PCESV)/(GDPDEF*CNP16OV))
Investment	I=log((FPI+CBI+PCDG)/(GDPDEF*CNP16OV))
Output	Y=log(GDP/(GDPDEF*CNP16OV))
Fiscal Receipts	F=log(GRECPT/(GDPDEF*CNP16OV))
Real Wage	W=log(COMPNFB/GDPDEF)
Hours Worked	L=log(HOANBS/CNP16OV)
Inflation Rate	π=log(GDPDEF)-log(GDPDEF)$_{-1}$*4
Nominal Interest Rate	R=FEDFUNDS

2.B Derivation of log-linearized baseline model

This appendix reports the first order conditions for the optimization problems described in the paper and other relationships that define the equilibrium of the baseline model. Further, it presents the model's steady state and its log-linear approximation.

2.B.1 Final goods producers

The final good, Y_t, is formed by combining intermediate goods according to a standard Dixit-Stiglitz technology

$$Y_t = \left(\int_0^1 Y_t(i)^{\frac{1}{1+\varepsilon_t^p}} \mathrm{d}i \right)^{1+\varepsilon_t^p} \tag{2.B.1}$$

The demand for intermediate goods is derived from profit maximization, where profits are given by

$$\max_{Y_t} P_t Y_t - \int_0^1 P_t(i) Y_t(i) \mathrm{d}i$$

where P_t and $P_t(i)$ denote, respectively, the price of the final and intermediate goods respectively. $\varepsilon_t^p \in (0, \infty)$ is an exogenous process that reflects shocks to the aggregating function that results in changes in the elasticity of demand and therefore in the mark–up. ε_t^p follows the exogenous ARMA process

$$\log \varepsilon_t^p = (1-\rho_p) \log \overline{\varepsilon}^p + \rho_p \log \varepsilon_{t-1}^p - \theta_p \epsilon_{t-1}^p + \epsilon_t^p, \qquad \epsilon_t^p \sim N(0, \sigma_p)$$

The optimal demand for good i is then given by

$$Y_t(i) = \left(\frac{P_t(i)}{P_t} \right)^{-\frac{1+\varepsilon_t^p}{\varepsilon_t^p}} Y_t \tag{2.B.2}$$

Perfect competition on the final good market drives profits to zero. Using the zero profit condition together with Equation (2.B.2)), one gets the aggregate price level as

$$P_t = \left(\int_0^1 P_t(i)^{-\frac{1}{\varepsilon_t^p}} \mathrm{d}i \right)^{-\varepsilon_t^p} \tag{2.B.3}$$

2.B.2 Intermediate goods producers

Intermediate producer $i \in (0,1)$ produces a specific good by means of capital, $K_t^s(i)$, and labor services, $L_t(i)$, according to the technology represented by the production function

$$Y_t(i) = \varepsilon_t^a K_t^s(i)^\alpha L_t(i)^{1-\alpha} - \Phi \tag{2.B.4}$$

where $\alpha \in (0,1)$, $\Phi > 0$ is a fixed cost. ε_t^a is a total factor productivity and follows following process

$$\log \varepsilon_t^a = (1-\rho_a)\log \overline{\varepsilon}^a + \rho_a \log \varepsilon_{t-1}^a + \epsilon_t^a, \qquad \epsilon_t^a \sim N(0,\sigma_a)$$

The presence of a fixed cost makes technology exhibit increasing returns to scale which, together with the fact that intermediate i is the sole producer of good i and the elasticity of substitution is finite in the final good bundle, implies that the intermediate good has monopoly power on its market. Note however that the firm is price taker on the market for inputs.

The production plan is obtained by standard cost minimization that leads to the capital labor ratio

$$\frac{K_t^s(i)}{L_t(i)} = \frac{\alpha}{1-\alpha}\frac{W_t}{P_t R_t^k}$$

where W_t/P_t denotes the real wage paid to the labor packers, and R_t^k is the real rental rate of capital. Note that the capital labor ratio is in fact independent from the firm's type i.

The aggregate real marginal cost, s_t, is then given by

$$s_t = \frac{W_t L_t}{(1-\alpha)\varepsilon_t^a {K_t^s}^\alpha L_t^{1-\alpha}}$$

which, using the capital labor ratio can be rewritten as

$$s_t = \frac{{R_t^k}^\alpha (W_t/P_t)^{1-\alpha}}{\alpha^\alpha (1-\alpha)^{1-\alpha}\varepsilon_t^a}$$

2.B.3 The price setting

Intermediate goods producers are monopolistically competitive, and are therefore price setters. However, following Calvo (1983), they only get a chance to set their price in the current period with probability ξ_p, with the complement probability they index their former price to steady state and past inflation according to

$$P_t(i) = \overline{\pi}^{1-\iota_p}\pi_{t-1}^{\iota_p}P_{t-1}(i)$$

where $\iota_p \in [0,1]$ controls for the degree of backward indexation. Accordingly, a firm that resets its price in the current period sets it so as to maximize the profits

$$\max_{\widetilde{P}_t(i)} E_t\left[\sum_{k=0}^{\infty}\xi_p^k\Psi_{t,t+k}\left(\Omega_{t,t+k}^p\widetilde{P}_t(i) - s_{t+k}\right)Y_{t+k}(i)\right]$$

subject to the total demand it faces (Equation 2.B.2)), where $\Psi_{t,t+k}$ is a proper stochastic discount factor and $\Omega_{t,t+k}^p$ is a term that keeps track of the nominal growth component

$$\Omega_{t,t+k}^p \equiv \begin{cases} 1 & \text{if } k = 0 \\ \Omega_{t,t+k-1}^p\pi_{t+k-1}^{\iota_p}\overline{\pi}^{1-\iota_p} & \text{if } k > 0 \end{cases}$$

The optimality condition associated to the price setting behavior is

$$E_t\left[\sum_{k=0}^{\infty}(1-\xi_p)^k\Psi_{t,t+k}\left(\Omega_{t,t+k}^pY_{t+k}(i) + \left(\Omega_{t,t+k}^p\widetilde{P}_t(i) - P_{t+k}s_{t+k}\right)\frac{\partial Y_{t+k}(i)}{\partial\widetilde{P}_t(i)}\right)\right] = 0$$

which, using the form of the demand function, simplifies to

$$E_t\left[\sum_{k=0}^{\infty}(1-\xi_p)^k\Psi_{t,t+k}\frac{Y_{t+k}(i)}{\varepsilon_{t+k}^p}\left(\Omega_{t,t+k}^p\widetilde{P}_t - (1+\varepsilon_{t+k}^p)P_{t+k}s_{t+k}\right)\right] = 0 \qquad (2.B.5)$$

or

$$\widetilde{P}_t = \frac{N_t^p}{D_t^p}$$

where

$$N_t^p = E_t\left[\sum_{k=0}^{\infty}(1-\xi_p)^k\Psi_{t,t+k}\frac{Y_{t+k}(i)}{\varepsilon_{t+k}^p}(1+\varepsilon_{t+k}^p)P_{t+k}s_{t+k}\right]$$
$$D_t^p = E_t\left[\sum_{k=0}^{\infty}(1-\xi_p)^k\Psi_{t,t+k}\frac{Y_{t+k}(i)}{\varepsilon_{t+k}^p}\Omega_{t,t+k}^p\right]$$

Using the Poisson property of the Calvo setting, the aggregate price index (2.B.3) rewrites

$$P_t = \left(\xi_p\widetilde{P}_t(i)^{-\frac{1}{\varepsilon_t^p}} + (1-\xi_p)(\pi_{t-1}^{\iota_p}\overline{\pi}^{1-\iota_p}P_{t-1})^{-\frac{1}{\varepsilon_t^p}}\right)^{-\varepsilon_t^p} \qquad (2.B.6)$$

2.B.4 Households

Households $j \in (0,1)$ chooses consumption C_t, hours worked $L_t(j)$, bonds B_t, investment I_t and capital utilization Z_t, so as to maximize the following objective function

$$E_t \sum_{t=0}^{\infty} \beta^t \varepsilon_t^b \left(\log(C_t - \chi C_{t-1}) - \vartheta \frac{L_t(j)^{1+\nu}}{1+\nu} \right) \tag{2.B.7}$$

subject to the budget constraint and the capital accumulation

$$\begin{aligned}(1+\tau_t^c)P_t C_t + P_t I_t + \frac{B_t}{R_t} =& B_{t-1} + (1-\tau_t^w)W_t(j)L_t(j) \\ &+ (1-\tau_t^k)P_t R_t^k Z_t K_t - P_t \Phi_z(Z_t)K_t + \Pi_t + P_t T_t \end{aligned} \tag{2.B.8}$$

$$K_{t+1} = \varepsilon_t^i \left(1 - \Phi_i \left(\frac{I_t}{I_{t-1}} \right) \right) I_t + (1-\delta)K_t \tag{2.B.9}$$

ε_t^b and ε_t^i are both assumed to follow stationary AR(1) stochastic processes, as described in the main text.

$$\log \varepsilon_t^b = \rho_b \log \varepsilon_{t-1}^b + \epsilon_t^b$$
$$\log \varepsilon_t^i = \rho_i \log \varepsilon_{t-1}^i + \epsilon_t^i$$

where $|\rho_b| < 1$, $\epsilon_t^b \sim N(0, \sigma_b)$, $|\rho_i| < 1$ and $\epsilon_t^i \sim N(0, \sigma_i)$.

Household's optimality conditions are as follows

$$\begin{aligned}(1+\tau_t^c)P_t\Lambda_t =& \frac{\varepsilon_t^b}{(C_t - \chi C_{t-1})} - E_t \frac{\beta \chi \varepsilon_{t+1}^b}{(C_{t+1} - \chi C_t)} \\ 1 =& Q_t \varepsilon_t^i \left(1 - \Phi_i \left(\frac{I_t}{I_{t-1}} \right) - \Phi_i' \left(\frac{I_t}{I_{t-1}} \right) \frac{I_t}{I_{t-1}} \right) \\ &+ \beta E_t \left[\frac{P_{t+1}\Lambda_{t+1}}{P_t \Lambda_t} Q_{t+1} \varepsilon_{t+1}^i \Phi_i' \left(\frac{I_{t+1}}{I_t} \right) \frac{I_{t+1}^2}{I_t^2} \right] \\ \Lambda_t =& \beta R_t E_t \left[\Lambda_{t+1} \right] \\ Q_t =& \beta E_t \frac{P_{t+1}\Lambda_{t+1}}{P_t\Lambda_t} \Big((1-\tau_{t+1}^k) R_{t+1}^k Z_{t+1} - \Phi_z(Z_{t+1}) + (1-\delta) Q_{t+1} \Big) \\ \Phi_z'(Z_t) =& (1-\tau_t^k) R_t^k \end{aligned}$$

and in the flexible wage allocation only

$$\varepsilon_t^b \vartheta L_t^\nu = (1-\tau_t^w)\Lambda_t W_t$$

where Λ_t and $P_t \Lambda_t Q_t$ denote the Lagrange multipliers associated to the budget constraint and capital accumulation constraint, respectively. The definition of the Lagrange multiplier of the law of motion of capital permits to obtain explicitly the marginal Tobin's Q Q_t in terms of goods, rather than in utility terms. The last equation, the marginal disutility of working, is reported here as it will be relevant later for the computation of flexible price equilibrium. Otherwise the optimal wage will be obtained from the wage contracts as explained in the next section.

2.B.5 Wage Settings (Intermediate labor union sector)

Each household supplies a continuum of differentiated type of labor service, $L_t(i)$, to the labor market. These differentiated labor inputs are purchased by a representative competitive firm referred to as a labor packer. The labor packer then assembles the differentiated labor inputs to produce a composite labor service, L_t, by using a Dixit–Stiglitz aggregating technology

Labor used by the intermediate goods producers L_t is a composite

$$L_t = \left(\int_0^1 L_t(j)^{\frac{1}{1+\varepsilon_t^w}} \mathrm{d}j \right)^{1+\varepsilon_t^w}$$

There are **labor packers** who buy the labor from the unions, package L_t, and resell it to the intermediate goods producers. Labor packers maximize profits in a perfectly competitive market. From the first–order conditions of the labor packers one obtains

$$L_t(j) = \left(\frac{W_t(j)}{W_t} \right)^{-\frac{1+\varepsilon_t^w}{\varepsilon_t^w}} L_t \tag{2.B.10}$$

Combining this condition with the zero profit condition one obtains an expression for the wage cost for the intermediate goods producers

$$W_t = \left(\int_0^1 W_t(j)^{-\frac{1}{\varepsilon_t^w}} \mathrm{d}j \right)^{-\varepsilon_t^w} \tag{2.B.11}$$

It is assumed that ε_t^w follows an exogenous ARMA process

$$\log \varepsilon_t^w = (1-\rho_w)\log \overline{\varepsilon}^w + \rho_w \log \varepsilon_{t-1}^w - \theta_w \epsilon_{t-1}^w + \epsilon_t^w, \quad \epsilon_t^w \sim N(0,\sigma_w)$$

I follow Smets and Wouters (2007) and assume that labor packers buy the labor from the unions, which act as intermediate between the households and the labor packers. Unions have monopoly power over type j labor and set the wage, internalizing the labor demand 2.B.10. The union takes the marginal rate of substitution between consumption and leisure as the cost of labor services, W_t^h:

$$W_t^h = \frac{L_t^\nu}{(1-\tau_t^w)\Lambda_t}$$

The wage is set then by applying a markup over this cost. However, just like the intermediate good producers, unions are subject to the willingness of the Calvo fairy and can only set the wage in the current period with probability $\xi_w \in (0,1)$. When it is not select to re-optimize the wage, it can index it on steady state and past inflation as $W_t(j) = \overline{\pi}^{1-\iota_w}\pi_{t-1}^{\iota_w} W_{t-1}(j)$. A firm that can re-optimize the wage in the current period selects a wage $\widetilde{W}_t(j)$ by solving the program

$$\max_{\widetilde{W}_t(j)} E_t\left[\sum_{k=0}^{\infty}(1-\xi_w)^k \Psi_{t,t+k}\left((\widetilde{W}_t(j)\Omega_{t,t+k}^w - W_{t+k}^h)L_{t+k}(j)\right)\right] \tag{2.B.12}$$

subject to the demand for labor of type j (Equation 2.B.10). In the latter equation, $\Psi_{t,t+k}$ is a proper discount factor and where $\Omega_{t,t+k}^w$ is defined as

$$\Omega_{t,t+k}^w \equiv \begin{cases} 1 & \text{if } k=0 \\ \Omega_{t,t+k-1}^w \pi_{t+k-1}^{\iota_w} \overline{\pi}^{1-\iota_w} & \text{if } k>0 \end{cases} \tag{2.B.13}$$

The first order condition associated to the wage setting is given by

$$E_t\left[\sum_{k=0}^{\infty}(1-\xi_w)^k \Psi_{t,t+k}\left(\Omega_{t,t+k}^w L_{t+k}(j) + (\widetilde{W}_t(j)\Omega_{t,t+k}^w - W_{t+k}^h)\frac{\partial L_{t+k}(j)}{\partial \widetilde{W}_t(j)}\right)\right] = 0$$

which, in the case of the particular demand function (2.B.10) rewrites

$$E_t\left[\sum_{k=0}^{\infty}(1-\xi_w)^k \Psi_{t,t+k}\frac{L_{t+k}(j)}{\varepsilon_{t+k}^w}\left(\widetilde{W}_t(j)\Omega_{t,t+k}^w - (1+\varepsilon_{t+k}^w)W_{t+k}^h)\right)\right] = 0 \tag{2.B.14}$$

or

$$\widetilde{W}_t = \frac{N_t^w}{D_t^w}$$

where

$$N_t^w = E_t\left[\sum_{k=0}^{\infty}(1-\xi_p)^k \Psi_{t,t+k}\frac{L_{t+k}(i)}{\varepsilon_{t+k}^w}(1+\varepsilon_{t+k}^w)W_{t+k}^h\right]$$
$$D_t^w = E_t\left[\sum_{k=0}^{\infty}(1-\xi_p)^k \Psi_{t,t+k}\frac{L_{t+k}(i)}{\varepsilon_{t+k}^w}\Omega_{t,t+k}^w\right]$$

Using the Poisson property of the Calvo scheme, the aggregate wage index (2.B.11) rewrites

$$W_t = \left(\xi_w \widetilde{W}_t^{\frac{1}{\varepsilon_t^w}} + (1-\xi_w)(\pi_{t-1}^{\iota_w}\overline{\pi}^{1-\iota_w}W_{t-1})^{\frac{1}{\varepsilon_t^w}}\right)^{\varepsilon_t^w} \tag{2.B.15}$$

2.B.6 Monetary and Fiscal Policies

The central bank follows a nominal interest rate rule by adjusting its instrument in response to deviations of inflation and output from their respective target levels

$$R_t = (1-\rho_r)\left(\overline{R} + \kappa_y \log\left(\frac{Y_t}{\overline{Y}}\right) + \kappa_\pi \log\left(\frac{\pi_t}{\overline{\pi}}\right)\right) + \rho_r R_{t-1} + \varepsilon_t^r \tag{2.B.16}$$

where $\overline{R}$ is the steady state nominal rate (gross rate) and $\overline{Y}$ is the natural output. The parameter ρ_r determines the degree of interest rate smoothing. The monetary policy shock ε_t^r is determined as

$$\varepsilon_t^r = \rho_r \varepsilon_{t-1}^r + \epsilon_t^r$$

The government budget constraint is of the form

$$B_t = R_{t-1}B_{t-1} + P_t G_t - F_t \tag{2.B.17}$$

The government spending expressed relative to the steady state output path $g_t = \frac{G_t}{Y}$ follows the exogenous stochastic process, whose properties are defined as

$$\log g_t = (1-\rho_g)\log\overline{g} + \rho_g \log g_{t-1} + \rho_{ga}\epsilon_t^a + \epsilon_t^g, \quad \epsilon_t^g \sim N(0,\sigma_g)$$

The fiscal authority abides by following fiscal rule

$$F_t = F^\star \exp\left(\gamma_y(\log Y_t - \log \overline{Y}) + \gamma_d \frac{B_{t-1}/P_{t-1} - \overline{B}}{\overline{Y}} + \varepsilon^f_t\right) \tag{2.B.18}$$

where

$$\varepsilon^f_t = \rho_r \varepsilon^f_{t-1} + \epsilon^r_t$$

F_t are government fiscal receipts composed as

$$F_t = \tau^c_t C_t + \tau^w_t \int_0^1 \frac{W_t(j)}{P_t} L_t(j)\mathrm{d}j + \tau^k_t R^k_t \int_0^1 Z_t(j)K_t(j)\mathrm{d}j + T_t$$

where T_t are nominal lump–sum taxes (or subsidies) that also appear in household's budget constraint.

2.B.7 Aggregation

Using the fact that

$$W_t L_t = \int_0^1 W_t(j)L_t(j)\mathrm{d}j, \quad K^s_t = \int_0^1 K^s_t(j)\mathrm{d}j$$

and the government budget constraint, aggregating the individual budget constraints yields

$$\begin{aligned}(1+\tau^c_t)P_tC_t + P_tI_t + P_tT_t =& (1-\tau^w_t)W_tL_t + (1-\tau^k_t)P_tR^k_tK^s_t - P_t\varphi(Z_t)K_t + \Pi_t \\ &+ \tau^c_t P_tC_t + \tau^w_t W_tL_t + \tau^k_t)P_tR^k_tK^s_t + P_tT_t - P_tG_t\end{aligned}$$

and simplifies to

$$P_tC_t + P_tI_t + P_tG_t + P_t\varphi(Z_t)K_t = W_tL_t + P_tR^k_tK^s_t + \Pi_t$$

The aggregate profits in the economy are given by

$$\Pi_t = \int_0^1 P_t(i)Y_t(i) - W_t(i)L_t(i) - P_tR^k_tK^s_t(i)\mathrm{d}i$$

which rewrites as

$$\Pi_t = P_tY_t - W_tL_t - P_tR^k_tK^s_t$$

Plugging in the aggregated budget constraint,

$$P_t Y_t = P_t C_t + P_t I_t + P_t G_t + P_t \Phi_z(Z_t) K_t$$

Note that the data only permit the observation of

$$\overline{Y}_t = \int_0^1 Y_t(i)\mathrm{d}i = \int_0^1 \left(\frac{P_t(i)}{P_t}\right)^{-\frac{1+\varepsilon_t^p}{\varepsilon_t^p}} Y_t \mathrm{d}i = \int_0^1 \left(\frac{P_t(i)}{P_t}\right)^{-\frac{1+\varepsilon_t^p}{\varepsilon_t^p}} \mathrm{d}i Y_t = \left(\frac{\overline{P}_t}{P_t}\right)^{-\frac{1+\varepsilon_t^p}{\varepsilon_t^p}} Y_t$$

where $\overline{P}_t$ is given by

$$\overline{P}_t = \left(\int_0^1 P_t(i)^{-\frac{1+\varepsilon_t^p}{\varepsilon_t^p}} \mathrm{d}i\right)^{-\frac{\varepsilon_t^p}{1+\varepsilon_t^p}} = \left(\xi_p \widetilde{P}_t^{-\frac{1+\varepsilon_t^p}{\varepsilon_t^p}} + (1-\xi_p)(\overline{\pi}^{1-\iota_p}\pi_{t-1}^{\iota_p}\overline{P}_{t-1})^{-\frac{1+\varepsilon_t^p}{\varepsilon_t^p}}\right)^{-\frac{\varepsilon_t^p}{1+\varepsilon_t^p}}$$

Likewise for labor

$$\overline{L}_t = \int_0^1 L_t(j)\mathrm{d}j = \int_0^1 \left(\frac{W_t(i)}{W_t}\right)^{-\frac{1+\varepsilon_t^w}{\varepsilon_t^w}} L_t \mathrm{d}j = \int_0^1 \left(\frac{W_t(j)}{W_t}\right)^{-\frac{1+\varepsilon_t^w}{\varepsilon_t^w}} \mathrm{d}j L_t = \left(\frac{\overline{W}_t}{W_t}\right)^{-\frac{1+\varepsilon_t^w}{\varepsilon_t^w}} L_t$$

where $\overline{W}_t$ is given by

$$\overline{W}_t = \left(\int_0^1 W_t(j)^{-\frac{1+\varepsilon_t^w}{\varepsilon_t^w}} \mathrm{d}j\right)^{-\frac{\varepsilon_t^w}{1+\varepsilon_t^w}} = \left(\xi_w \widetilde{W}_t^{-\frac{1+\varepsilon_t^w}{\varepsilon_t^w}} + (1-\xi_w)(\overline{\pi}^{1-\iota_w}\pi_{t-1}^{\iota_w}\overline{W}_{t-1})^{-\frac{1+\varepsilon_t^w}{\varepsilon_t^w}}\right)^{-\frac{\varepsilon_t^w}{1+\varepsilon_t^w}}$$

Using the fact that the capital labor ratio is independent from the firm's type, we have

$$\int_0^1 Y_t(i)\mathrm{d}i = \overline{Y}_t = \varepsilon_t^a \left(\frac{K_t^s}{L_t}\right)^\alpha \int_0^1 L_t(i)\mathrm{d}i - \Phi$$

which yields

$$\overline{Y}_t = \varepsilon_t^a \left(\frac{K_t^s}{L_t}\right)^\alpha \overline{L}_t - \Phi$$

which rewrites

$$\left(\frac{\overline{P}_t}{P_t}\right)^{-\frac{1+\varepsilon_t^p}{\varepsilon_t^p}} Y_t = \left(\frac{\overline{W}_t}{W_t}\right)^{-\frac{1+\varepsilon_t^w}{\varepsilon_t^w}} \varepsilon_t^a (Z_t K_t)^\alpha L_t^{1-\alpha} - \Phi$$

In a general equilibrium, the discount factor of the firm is proportional to the stochastic discount facor fo teh household such that $\Psi_{t,t+k} \propto \beta^k \Lambda_{t+k}/\Lambda_t$, then

$$\widetilde{P}_t = \frac{N_t^p}{D_t^p}$$

where

$$N_t^p = E_t\left[\sum_{k=0}^{\infty}(\beta(1-\xi_p))^k \frac{\Lambda_{t+k}}{\Lambda_t}\frac{Y_{t+k}(i)}{\varepsilon_{t+k}^p}(1+\varepsilon_{t+k}^p)P_{t+k}s_{t+k}\right]$$
$$D_t^p = E_t\left[\sum_{k=0}^{\infty}(\beta(1-\xi_p))^k \frac{\Lambda_{t+k}}{\Lambda_t}\frac{Y_{t+k}(i)}{\varepsilon_{t+k}^p}\Omega_{t,t+k}^p\right]$$

which can be recursively written as

$$N_t^p = \frac{Y_t(i)}{\varepsilon_t^p}(1+\varepsilon_t^p)P_t s_t + \beta(1-\xi_p)E_t\left[\frac{\Lambda_{t+1}}{\Lambda_t}N_{t+1}^p\right]$$
$$D_t^p = \frac{Y_t(i)}{\varepsilon_t^p} + \beta(1-\xi_p)E_t\left[\frac{\Lambda_{t+1}}{\Lambda_t}\overline{\pi}^{1-\iota_p}\pi_t^{\iota_p}D_{t+1}^p\right]$$

Likewise for the wage

$$\widetilde{W}_t = \frac{N_t^w}{D_t^w}$$

where

$$N_t^w = E_t\left[\sum_{k=0}^{\infty}(\beta(1-\xi_w))^k \frac{\Lambda_{t+k}}{\Lambda_t}\frac{L_{t+k}(i)}{\varepsilon_{t+k}^w}(1+\varepsilon_{t+k}^w)\frac{L_{t+k}^{\nu}}{(1-\tau_{t+k}^w)\Lambda_{t+k}}\right]$$
$$D_t^w = E_t\left[\sum_{k=0}^{\infty}(\beta(1-\xi_w))^k \frac{\Lambda_{t+k}}{\Lambda_t}\frac{L_{t+k}(i)}{\varepsilon_{t+k}^w}\Omega_{t,t+k}^w\right]$$

which can be recursively written as

$$N_t^w = \frac{L_t(i)}{\varepsilon_t^w}(1+\varepsilon_t^w)\frac{L_t^{\nu}}{(1-\tau_t^w)\Lambda_t} + \beta(1-\xi_w)E_t\left[\frac{\Lambda_{t+1}}{\Lambda_t}N_{t+1}^w\right]$$
$$D_t^w = \frac{L_t(i)}{\varepsilon_t^w} + \beta(1-\xi_w)E_t\left[\frac{\Lambda_{t+1}}{\Lambda_t}\overline{\pi}^{1-\iota_w}\pi_t^{\iota_w}D_{t+1}^w\right]$$

2.B.8 Exogenous processes

There are eight exogenous processes in the model: (i) technology process shock, ε_t^a, (ii) financial risk premium shock, ε_t^b, (iii) investment relative price shock, ε_t^i, (iv) monetary policy shock, ε_t^r, (v) wage mark–up shock, ε_t^w, (vi) price mark–up shock, ε_t^p, (vii) government expenditure shock, ε_t^g, and (viii) discretionary component of fiscal policy, ε_t^f.

$$
\begin{aligned}
\log \varepsilon_t^a =& \rho_a \log \varepsilon_{t-1}^a + \epsilon_t^a, \\
\log \varepsilon_t^b =& \rho_b \log \varepsilon_{t-1}^b + \epsilon_t^b, \\
\log \varepsilon_t^i =& \rho_i \log \varepsilon_{t-1}^i + \epsilon_t^i, \\
\log g_t =& \rho_g \log g_{t-1} + (1-\rho_g) \log \overline{g} + \rho_{ga} \epsilon_t^a + \epsilon_t^g, \\
\log \varepsilon_t^w =& \rho_w \log \varepsilon_{t-1}^w + (1-\rho_w) \log \overline{\varepsilon}^w + \epsilon_t^w - \theta_w \epsilon_{t-1}^w, \\
\log \varepsilon_t^p =& \rho_p \log \varepsilon_{t-1}^p + (1-\rho_p) \log \overline{\varepsilon}^p + \epsilon_t^p - \theta_p \epsilon_{t-1}^p, \\
\varepsilon_t^r =& \rho_r \varepsilon_{t-1}^r + \epsilon_t^r, \\
\varepsilon_t^f =& \varepsilon_{t-1}^f + \epsilon_t^f.
\end{aligned}
$$

2.B.9 Equilibrium Conditions

The set of equations characterizing the general equilibrium of the economy deflated for the nominal components is given by

The firm

$$\overline{p}_t^{-\frac{1+\varepsilon_t^p}{\varepsilon_t^p}} Y_t = \left(\frac{\overline{w}_t}{w_t}\right)^{-\frac{1+\varepsilon_t^w}{\varepsilon_t^w}} \varepsilon_t^a (Z_t K_t)^\alpha L_t^{1-\alpha} - \Phi \tag{2.B.19}$$

$$Z_t K_t = \frac{\alpha}{1-\alpha}\frac{w_t}{R_t^k} L_t \tag{2.B.20}$$

$$s_t = \frac{R_t^{k\,\alpha} w_t^{1-\alpha}}{\alpha^\alpha (1-\alpha)^{1-\alpha}\varepsilon_t^a} \tag{2.B.21}$$

$$K_{t+1} = \varepsilon_t^i \left(1 - \Phi_i\left(\frac{I_t}{I_{t-1}}\right)\right) I_t + (1-\delta) K_t \tag{2.B.22}$$

The household

$$(1+\tau_t^c)\lambda_t = \frac{\varepsilon_t^b}{(C_t - \chi C_{t-1})} - \beta\chi E_t \frac{\varepsilon_{t+1}^b}{(C_{t+1} - \chi C_t)} \tag{2.B.23}$$

$$\begin{aligned} 1 = {} & Q_t \varepsilon_t^i \left(1 - \Phi_i\left(\frac{I_t}{I_{t-1}}\right) - \Phi_i'\left(\frac{I_t}{I_{t-1}}\right)\frac{I_t}{I_{t-1}}\right) \\ & + \beta E_t \left[\frac{\lambda_{t+1}}{\lambda_t} Q_{t+1} \varepsilon_{t+1}^i \Phi_i'\left(\frac{I_{t+1}}{I_t}\right)\frac{I_{t+1}^2}{I_t^2}\right] \end{aligned} \tag{2.B.24}$$

$$\lambda_t = \beta R_t E_t \left[\frac{\lambda_{t+1}}{\pi_{t+1}}\right] \tag{2.B.25}$$

$$Q_t = \beta E_t \frac{\lambda_{t+1}}{\lambda_t}\Big((1-\tau_{t+1}^k) R_{t+1}^k Z_{t+1} - \Phi_z(Z_{t+1}) + (1-\delta) Q_{t+1}\Big) \tag{2.B.26}$$

$$\Phi_z'(Z_t) = (1-\tau_t^k) R_t^k \tag{2.B.27}$$

and in the flexible wage allocation only

$$\varepsilon_t^b \vartheta L_t^\nu = (1-\tau_t^w)\lambda_t w_t \tag{2.B.28}$$

Aggregate Resource Constraint

$$Y_t = C_t + I_t + G_t + \Phi_z(Z_t) K_t \tag{2.B.29}$$

Wages and Prices

$$1 = \left(\xi_p \tilde{p}_t^{\frac{1}{\varepsilon_t^p}} + (1-\xi_p) \left(\frac{\pi_{t-1}^{\iota_p} \overline{\pi}^{1-\iota_p}}{\pi_t} \right)^{\frac{1}{\varepsilon_t^p}} \right)^{\varepsilon_t^p} \tag{2.B.30}$$

$$\overline{p}_t = \left(\xi_p \tilde{p}_t^{-\frac{1+\varepsilon_t^p}{\varepsilon_t^p}} + (1-\xi_p) \left(\frac{\overline{\pi}^{1-\iota_p} \pi_{t-1}^{\iota_p}}{\pi_t} \overline{p}_{t-1} \right)^{-\frac{1+\varepsilon_t^p}{\varepsilon_t^p}} \right)^{-\frac{\varepsilon_t^p}{1+\varepsilon_t^p}} \tag{2.B.31}$$

$$\tilde{p}_t = \frac{n_t^p}{d_t^p} \tag{2.B.32}$$

$$n_t^p = \frac{Y_t(i)}{\varepsilon_t^p}(1+\varepsilon_t^p)s_t + \beta(1-\xi_p)E_t\left[\frac{\lambda_{t+1}}{\lambda_t} n_{t+1}^p\right] \tag{2.B.33}$$

$$d_t^p = \frac{Y_t(i)}{\varepsilon_t^p} + \beta(1-\xi_p)E_t\left[\frac{\lambda_{t+1}}{\lambda_t} \frac{\overline{\pi}^{1-\iota_p}\pi_t^{\iota_p}}{\pi_{t+1}} d_{t+1}^p\right] \tag{2.B.34}$$

$$w_t = \left(\xi_w \tilde{w}_t^{\frac{1}{\varepsilon_t^w}} + (1-\xi_w) \frac{\pi_{t-1}^{\iota_w} \overline{\pi}^{1-\iota_w}}{\pi_t} w_{t-1})^{\frac{1}{\varepsilon_t^w}} \right)^{\varepsilon_t^w} \tag{2.B.35}$$

$$\overline{w}_t = \left(\xi_w \tilde{w}_t^{-\frac{1+\varepsilon_t^w}{\varepsilon_t^w}} + (1-\xi_w) \left(\frac{\overline{\pi}^{1-\iota_w} \pi_{t-1}^{\iota_w}}{\pi_t} \overline{w}_{t-1} \right)^{-\frac{1+\varepsilon_t^w}{\varepsilon_t^w}} \right)^{-\frac{\varepsilon_t^w}{1+\varepsilon_t^w}} \tag{2.B.36}$$

$$\tilde{w}_t = \frac{n_t^w}{d_t^w} \tag{2.B.37}$$

$$n_t^w = \frac{L_t(i)}{\varepsilon_t^w}(1+\varepsilon_t^w)\frac{L_t^\nu}{(1-\tau_t^w)\lambda_t} + \beta(1-\xi_w)E_t\left[\frac{\lambda_{t+1}}{\lambda_t} n_{t+1}^w\right] \tag{2.B.38}$$

$$d_t^w = \frac{L_t(i)}{\varepsilon_t^w} + \beta(1-\xi_w)E_t\left[\frac{\lambda_{t+1}}{\lambda_t} \frac{\overline{\pi}^{1-\iota_w}\pi_t^{\iota_w}}{\pi_{t+1}} d_{t+1}^w\right] \tag{2.B.39}$$

Policies

$$R_t = (1-\rho_r)\left(\overline{R} + \kappa_y \log\left(\frac{I_t}{\overline{y}}\right) + \kappa_\pi \log\left(\frac{\pi_t}{\overline{\pi}}\right)\right) + \rho_r R_{t-1} + \varepsilon_t^r \tag{2.B.40}$$

$$b_t = \varepsilon_t^b \frac{R_{t-1}}{\pi_t} b_{t-1} + G_t - F_t \tag{2.B.41}$$

$$F_t = \tau_t^c C_t + \tau_t^w w_t L_t + \tau_t^k R_t^k Z_t K_t + T_t \tag{2.B.42}$$

$$F_t = F^\star \exp\left(\gamma_y(\log Y_t - \log \overline{Y}) + \gamma_d \frac{b_{t-1} - \overline{B}}{\overline{Y}} + \varepsilon_t^r\right) \tag{2.B.43}$$

where $b_t = B_t/P_t$, $w_t = W_t/P_t$, $\pi_t = P_t/P_{t-1}$, $\tilde{p}_t = \tilde{P}_t/P_t$, $\overline{p}_t = \overline{P}_t/P_t$, $\tilde{w}_t = \widetilde{W}_t/P_t$, $\overline{w}_t = \overline{W}_t/P_t$, $\lambda_t = \Lambda_t P_t$, $n_t^j = N_t^j/P_t$, $d_t^j = D_t^j/P_t$, $j = w, p$.

2.B.10 The system of log-linear equations

Before proceeding, note that, in the steady state, we have

$$\pi^\star = \overline{p}^\star = 1, w^\star = \overline{w}^\star$$

The fixed cost is computed such that, in the steady state, profit are zero.

$$\begin{aligned}
&-\frac{y^\star + \Phi}{y^\star}\left(-\frac{1+\varepsilon^w}{\varepsilon^w}(\widehat{\overline{w}}_t - \widehat{w}_t) + \widehat{\varepsilon}^a_t + \alpha(\widehat{z}_t + \widehat{k}_t) + (1-\alpha)\widehat{L}_t\right) \\
&-\frac{1+\varepsilon^p}{\varepsilon^p}\widehat{\overline{p}}_t + \widehat{y}_t = 0 && (2.B.44) \\
&\widehat{r}^k_t + \widehat{z}_t + \widehat{k}_t - \widehat{w}_t - \widehat{L}_t = 0 && (2.B.45) \\
&\widehat{s}_t + \widehat{\varepsilon}^a_t - \alpha\widehat{r}^k_t - (1-\alpha)\widehat{w}_t = 0 && (2.B.46) \\
&\widehat{k}_{t+1} - \delta\widehat{i}_t - \delta\widehat{\varepsilon}^i_t - (1-\delta)\widehat{k}_t = 0 && (2.B.47) \\
&(1+\beta\chi^2)\widehat{c}_t - \chi\widehat{c}_{t-1} - \beta\chi E_t\widehat{c}_{t+1} + (1-\beta\chi)(1-\chi)\widehat{\lambda}_t \\
&+(1-\beta\chi)(1-\chi)\frac{\tau^c}{1+\tau^c}\widehat{\tau}^c_t - (1-\chi)\widehat{\varepsilon}^b_t + \beta\chi(1-\chi)E_t\widehat{\varepsilon}^b_{t+1} = 0 && (2.B.48) \\
&\widehat{q}_t + \widehat{\varepsilon}^i_t - \varphi(1+\beta)\widehat{i}_t + \varphi\widehat{i}_{t-1} + \beta\varphi E_t\widehat{i}_{t+1} = 0 && (2.B.49) \\
&\widehat{\lambda}_t - \widehat{R}_t - E_t\widehat{\lambda}_{t+1} + E_t\widehat{\pi}_{t+1} = 0 && (2.B.50) \\
&\widehat{q}_t + \widehat{\lambda}_t - E_t\widehat{\lambda}_{t+1} - \beta(1-\delta)E_t\widehat{q}_{t+1} \\
&+(1-\beta(1-\delta))E_t\left[\widehat{r}^k_{t+1} - \frac{\tau^k}{1-\tau^k}\widehat{\tau}^k_{t+1}\right] = 0 && (2.B.51) \\
&\sigma_z\widehat{z}_t - \widehat{r}^k_t + \frac{\tau^k}{1-\tau^k}\widehat{\tau}^k_t = 0 && (2.B.52) \\
&\widehat{r}_t - \rho_r\widehat{r}_{t-1} - (1-\rho_r)\kappa_y\widehat{y}_t - (1-\rho_r)\kappa_\pi\widehat{\pi}_t - \widehat{\varepsilon}^r_t = 0 && (2.B.53) \\
&\widehat{\pi}_t - \frac{\xi_t(1-\beta(1-\xi_p))}{(1-\xi_p)(1+\beta\iota_p)}\widehat{s}_t - \frac{\iota_p}{1+\beta\iota_p}\widehat{\pi}_{t-1} - \frac{\beta}{1+\beta\iota_p}E_t\widehat{\pi}_{t+1} - \widehat{\varepsilon}^p_t = 0 && (2.B.54) \\
&\widehat{\overline{p}}_t - (1-\xi_p)\widehat{\overline{p}}_{t-1} = 0 && (2.B.55)
\end{aligned}$$

$$\begin{aligned}
&\left(1+\beta(1-\xi_w)^2\right)\widehat{w}_t-(1-\xi_w)\widehat{\xi}_{t-1}-\beta(1-\xi_w)E_t\left[\widehat{w}_{t+1}+\widehat{\pi}_{t+1}\right]\\
&+(1-\xi_w)(1+\beta\iota_w)\widehat{\pi}_t-\iota_w(1-\xi_w)\widehat{\pi}_{t-1}\\
&-\xi_w(1-\beta(1-\xi_w))\left[\nu\widehat{L}_t-\widehat{\lambda}_t+\frac{\tau^w}{1-\tau^w}\widehat{\tau}^w_t+\frac{\varepsilon^w}{1+\varepsilon^w}\widehat{\varepsilon}^w_t\right]=0 && (2.B.56)\\
&\widehat{\overline{w}}_t-\widehat{w}_t=0 && (2.B.57)\\
&\beta\frac{b^\star}{y^\star}(\widehat{b}_t-\widehat{r}_t)-\frac{b^\star}{y^\star}(\widehat{b}_{t-1}-\widehat{\pi}_t)+\frac{g^\star}{y^\star}\widehat{g}_t-\frac{f^\star}{y^\star}\widehat{f}_t=0 && (2.B.58)\\
&\frac{f^\star}{y^\star}\widehat{f}_t-\frac{\tau^c c^\star}{y^\star}(\widehat{\tau}^c_t+\widehat{c}_t)-\frac{\tau^w w^\star L^\star}{y^\star}(\widehat{\tau}^w_t+\widehat{w}_t+\widehat{L}_t)\\
&-\frac{\tau^k R^{k\star}k^\star}{y^\star}(\widehat{\tau}^k_t+\widehat{r}^k_t+\widehat{z}_t+\widehat{k}_t)-\frac{T^\star}{y^\star}\widehat{T}_t=0 && (2.B.59)\\
&\widehat{f}_t-\gamma_y\widehat{y}_t-\gamma_d\widehat{b}_{t-1}-\widehat{\varepsilon}^f_t=0 && (2.B.60)\\
&\widehat{y}_t-\frac{c^\star}{y^\star}\widehat{c}_t-\frac{i^\star}{y^\star}\widehat{i}_t-\frac{g^\star}{y^\star}\widehat{g}_t-\alpha(1-\tau^k)\widehat{z}_t=0 && (2.B.61)
\end{aligned}$$

where equation (2.B.54) was obtained by manipulating log-linear versions of Equations (2.B.30), (2.B.32)–(2.B.34). Equation (2.B.56) was obtained by combining log-linear versions of Equations (2.B.35), (2.B.37)–(2.B.39). Equation (2.B.55) was obtained by combining log-linear versions of Equations (2.B.30)–(2.B.31), while equation (2.B.57) was obtained by combining log-linear versions of Equations (2.B.35)–(2.B.36). Note that as long as the economy is started from a situation where $\overline{p}_t$ is at its steady state value, then $\widehat{\overline{p}}_t=0$, $\forall t$, and given that $\widehat{\overline{w}}_t=\widehat{w}_t$, then Equation (2.B.44) simplifies to

$$\widehat{y}_t-\frac{y^\star+\Phi}{y^\star}\left(\widehat{\varepsilon}^a_t+\alpha(\widehat{z}_t+\widehat{k}_t)+(1-\alpha)\widehat{L}_t\right)=0$$

2.B.11 Additional Tables and Figures

Figure 2.13: Convergence

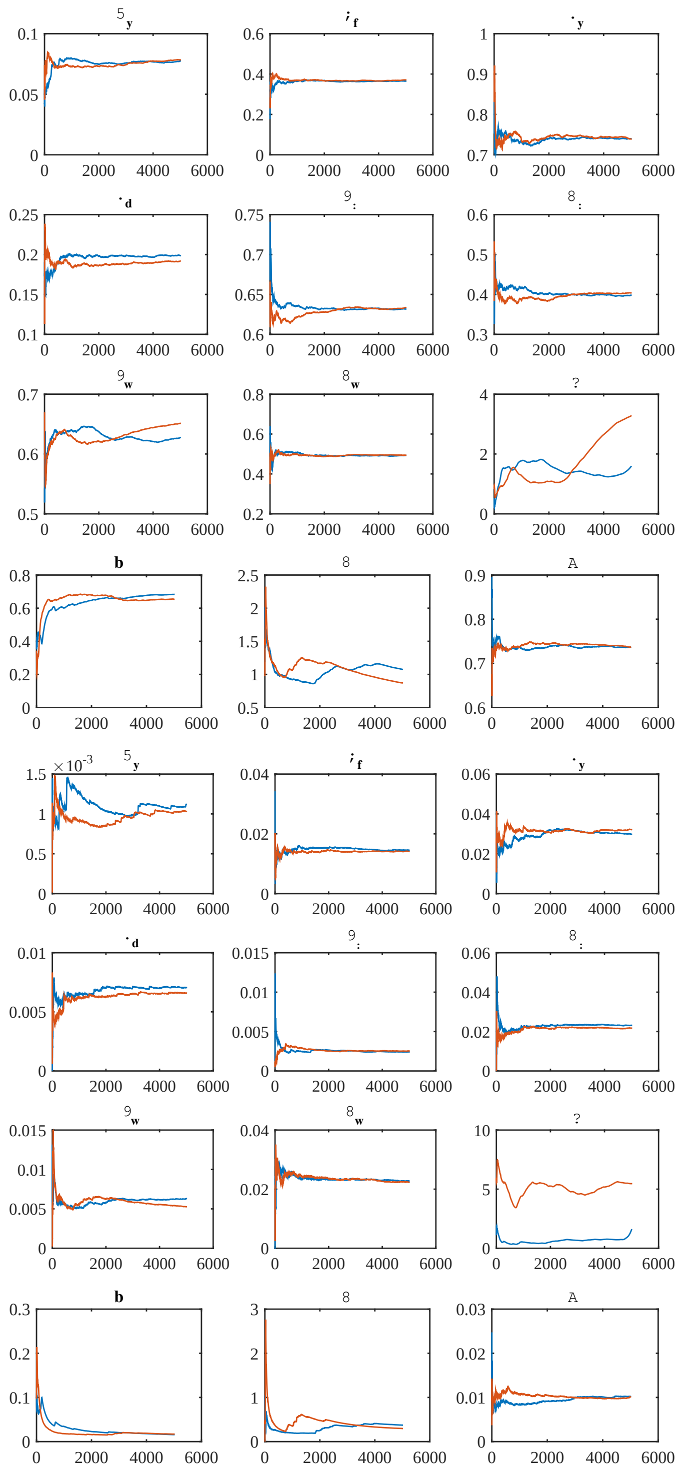
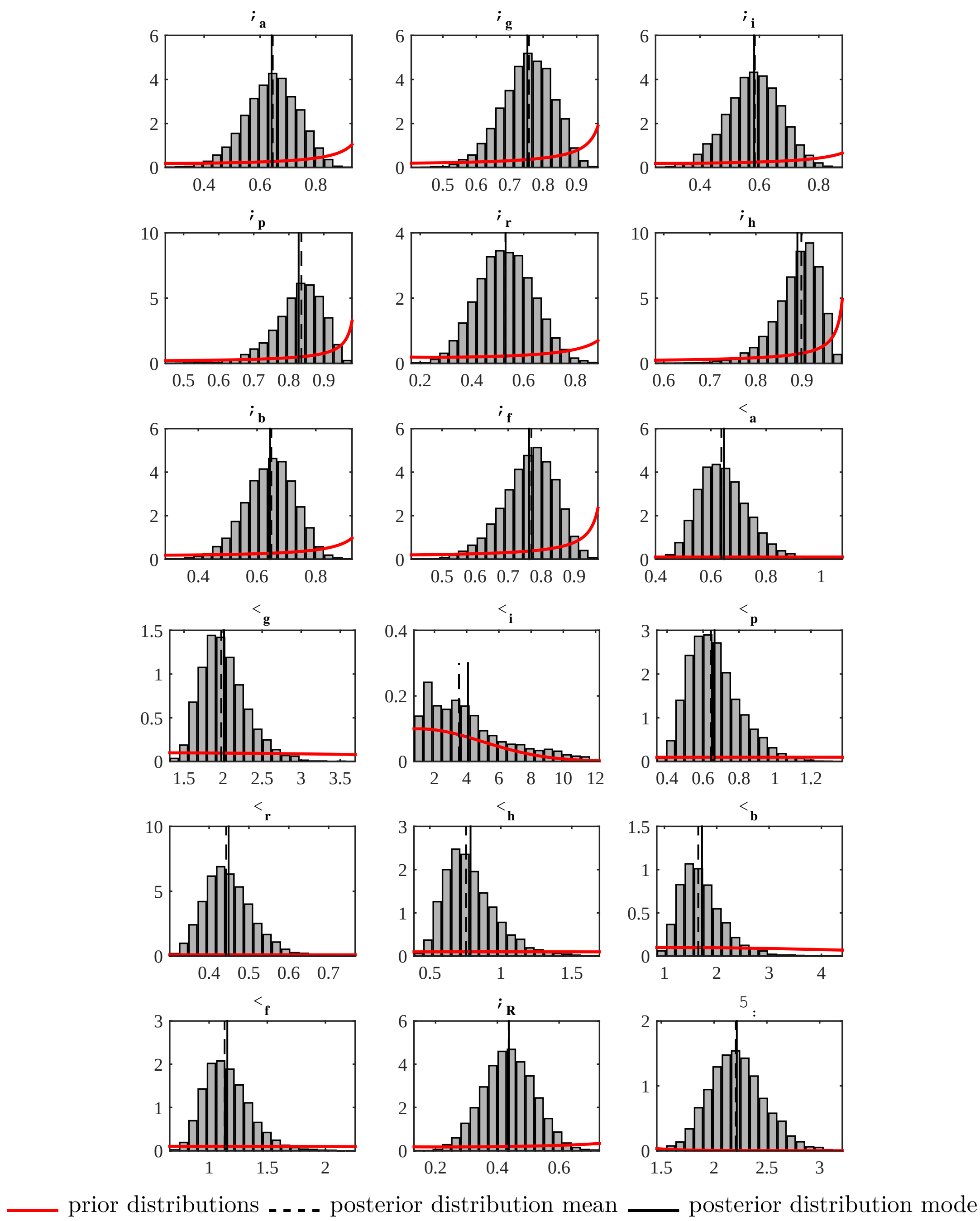
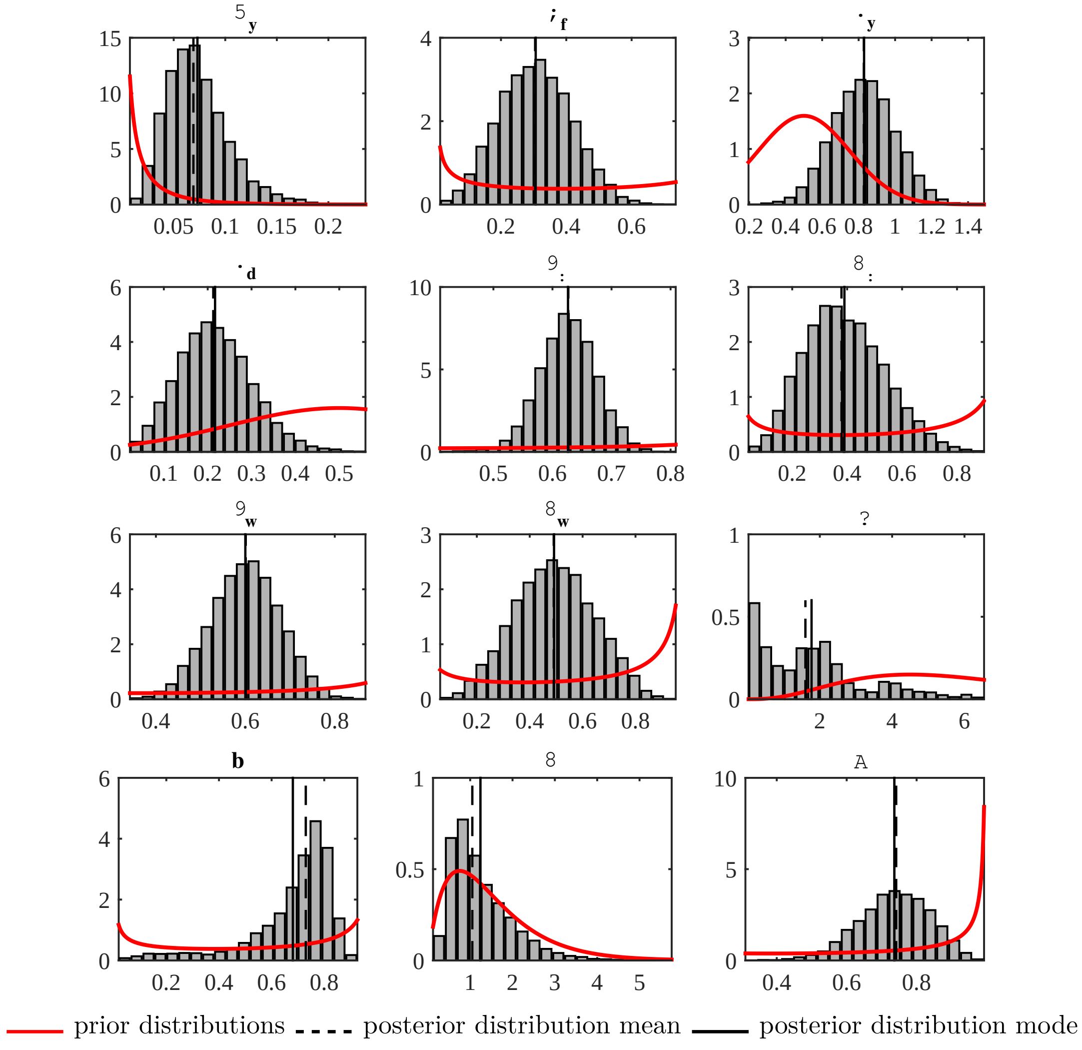


Figure 2.14: Prior and posterior distributions



Note: Posterior distributions are from the model where only labor taxes adjust.

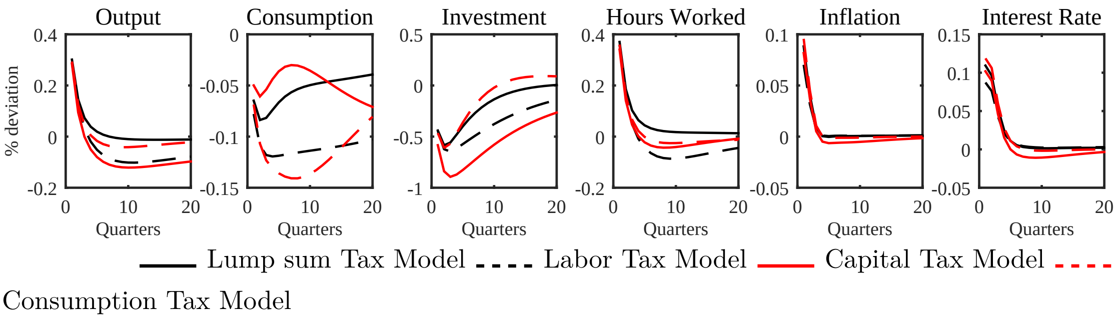
Figure 2.15: Prior and posterior distributions



Note: Posterior distributions are from the model where only labor taxes adjust.

3. Supplementary impulse responses for benchmark model

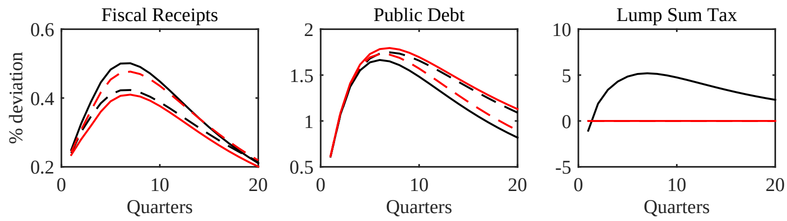
Figure 2.16: Macroeconomic Aggregates (1 std.dev. Government Expenditures Shock)



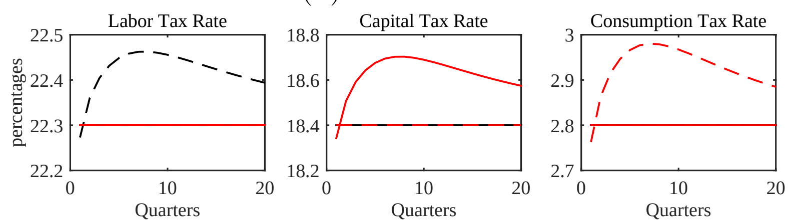
Note: Average of posterior distribution of IRFs.

Figure 2.17: Fiscal Policy (1 std.dev. Government Expenditures Shock)

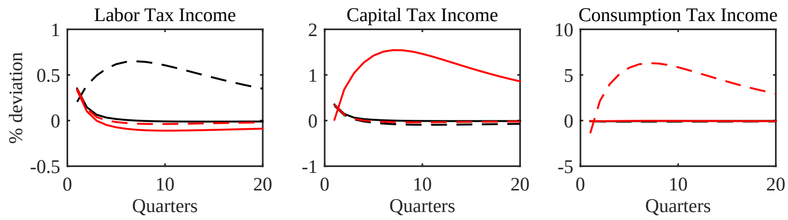
(a) Debt and Tax Receipts



(b) Tax Rates



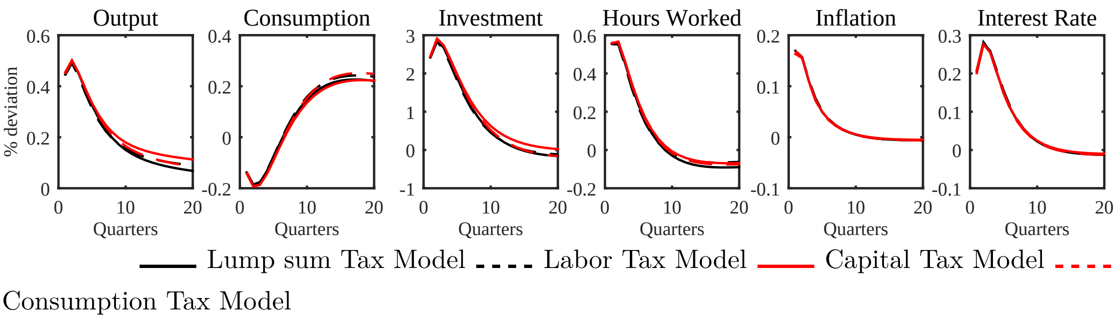
(c) Tax Revenues



Lump sum Tax Model Labor Tax Model Capital Tax Model Consumption Tax Model

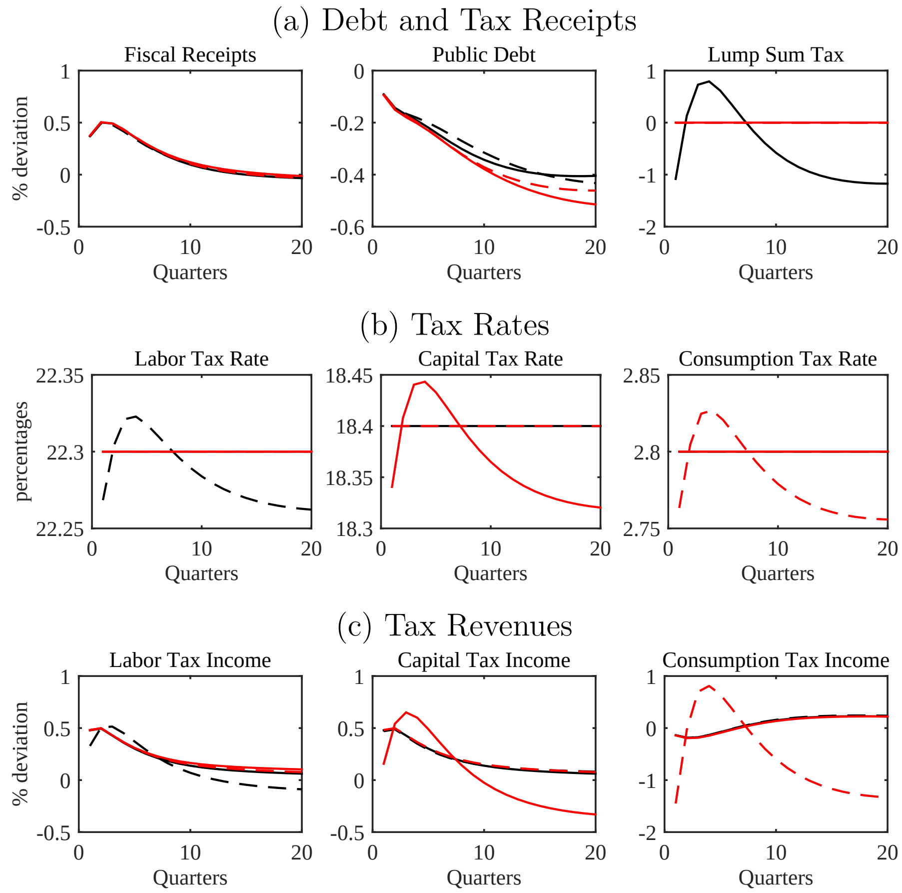
Note: Average of posterior distribution of IRFs.

Figure 2.18: Macroeconomic Aggregates (1 std.dev. Investment Efficiency Shock)



Note: Average of posterior distribution of IRFs.

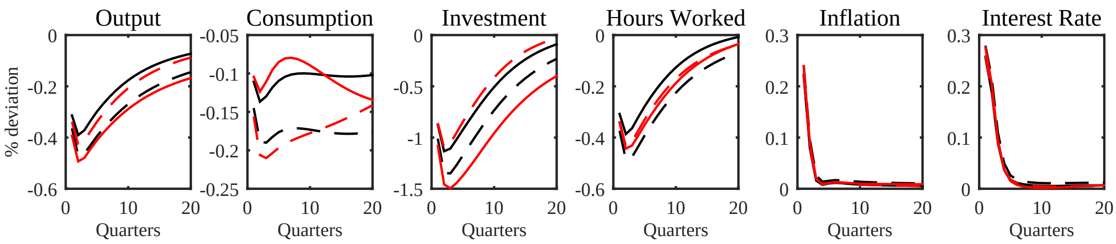
Figure 2.19: Fiscal Policy (1 std.dev. Investment Efficiency Shock)



Lump sum Tax Model Labor Tax Model Capital Tax Model Consumption Tax Model

Note: Average of posterior distribution of IRFs.

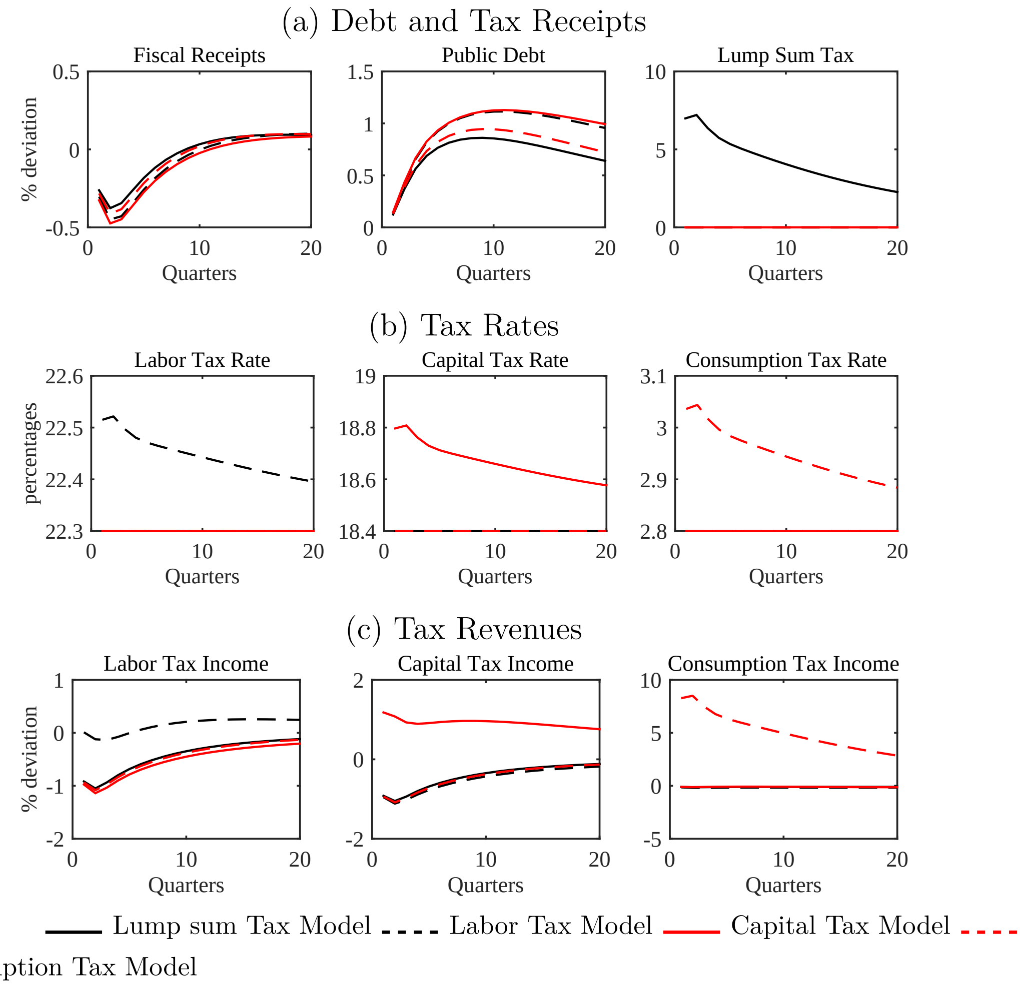
Figure 2.20: Macroeconomic Aggregates (1 std.dev. Cost Push Shock)



Lump sum Tax Model Labor Tax Model Capital Tax Model Consumption Tax Model

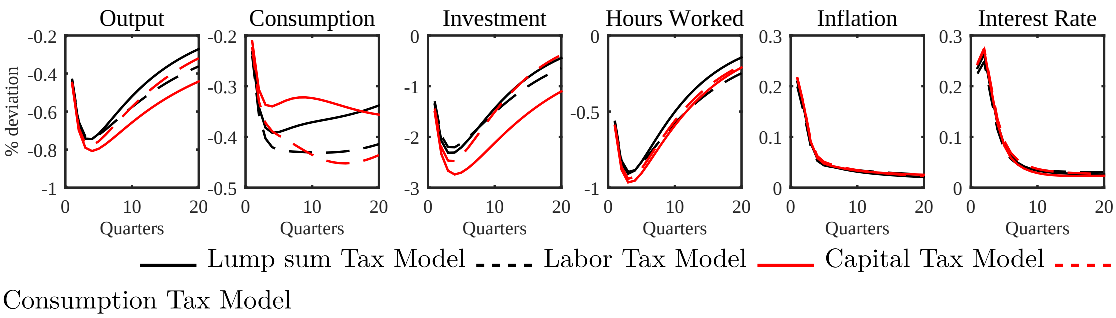
Note: Average of posterior distribution of IRFs.

Figure 2.21: Fiscal Policy (1 std.dev. Cost Push Shock)



Note: Average of posterior distribution of IRFs.

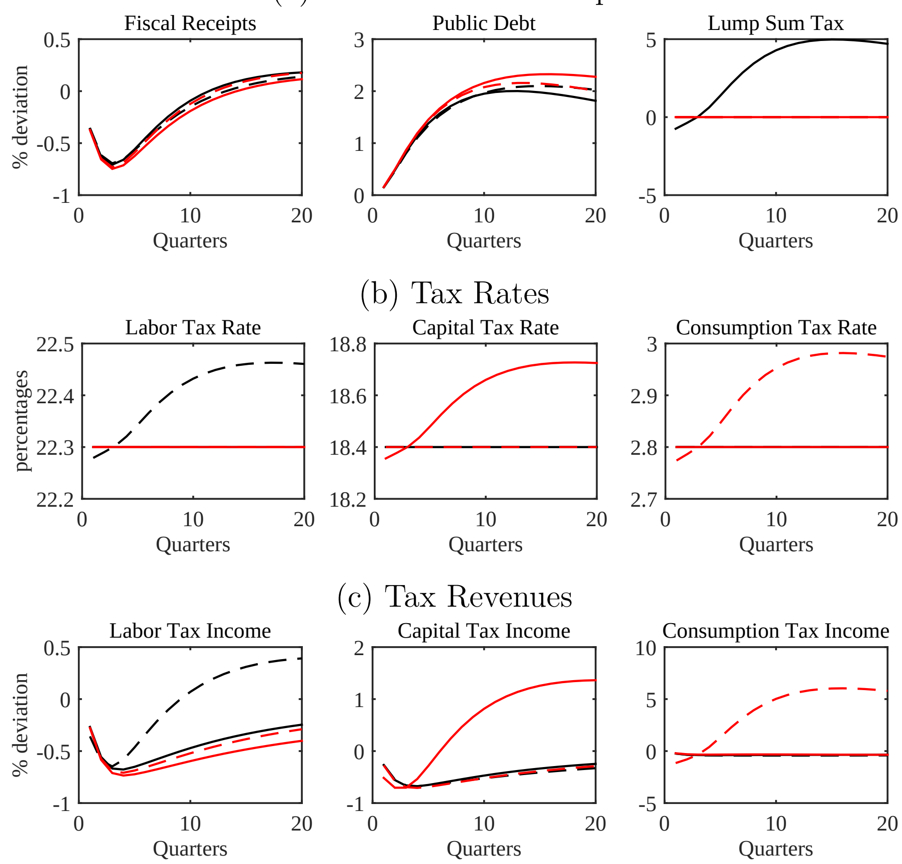
Figure 2.22: Macroeconomic Aggregates (1 std.dev. Wage Markup Shock)



Note: Average of posterior distribution of IRFs.

Figure 2.23: Fiscal Policy (1 std.dev. Wage Markup Shock)

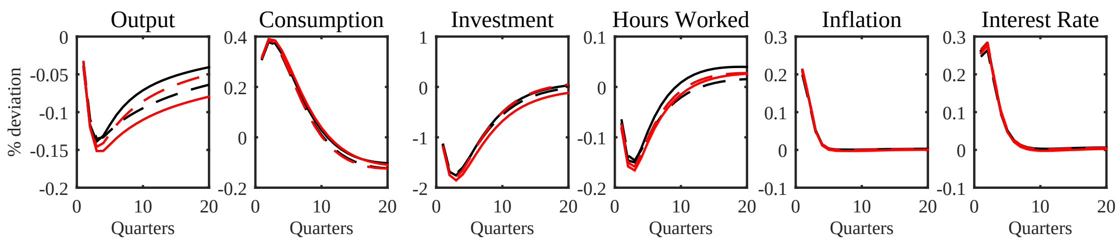
(a) Debt and Tax Receipts



Lump sum Tax Model Labor Tax Model Capital Tax Model Consumption Tax Model

Note: Average of posterior distribution of IRFs.

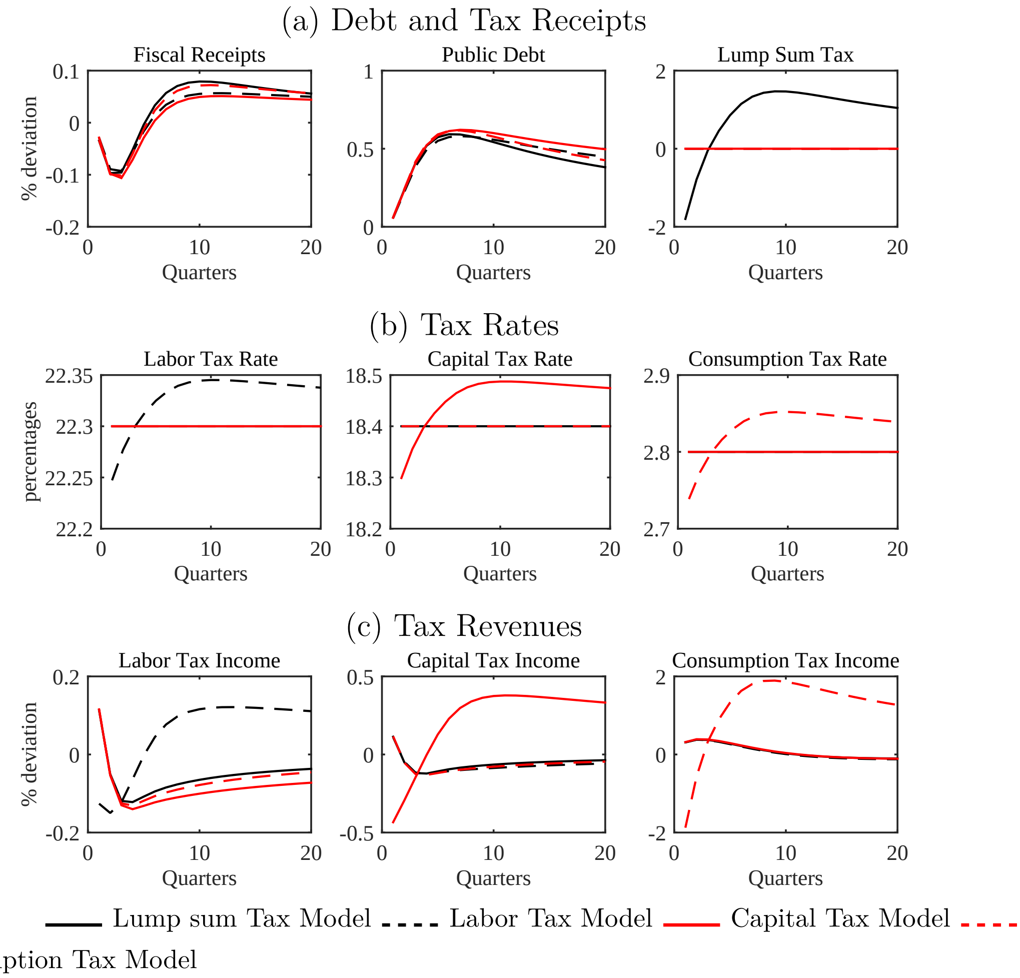
Figure 2.24: Macroeconomic Aggregates (1 std.dev. Preference Shock)



Lump sum Tax Model — Labor Tax Model — Capital Tax Model — Consumption Tax Model

Note: Average of posterior distribution of IRFs.

Figure 2.25: Fiscal Policy (1 std.dev. Preference Shock)



Note: Average of posterior distribution of IRFs.

3. Sensitivity Analysis

3.1 Monetary Policy

Table 2.16: Tax Elasticities of output (20 periods horizon): Varying Monetary Policy

	Benchmark	Inflation		Output	
Shock	Estimate	$\kappa_\pi = 1$	$\kappa_\pi = \infty$	$\kappa_y = 0$	$\kappa_y = 0.5$
		Lump Sum Tax Model			
Technology	-0.038	-0.007	-0.054	-0.039	-0.043
Government Expenditures	-0.013	-0.006	-0.009	-0.013	-0.014
Investment Efficiency	-0.028	-0.127	0.020	-0.029	-0.036
Cost Push	-0.042	-0.053	-0.033	-0.041	-0.047
Monetary Policy	-0.012	-0.013	-0.008	-0.012	-0.012
Wage Markup	-0.092	-0.031	-0.144	-0.092	-0.092
Preference	-0.037	-0.025	-0.032	-0.037	-0.039
Discretionary Fiscal Policy	0.000	-0.000	0.000	0.000	0.000
Std(y)	1.574	1.583	1.660	1.580	1.516
		Capital Tax Model			
Technology	-0.200	-0.125	-0.244	-0.200	-0.219
Government Expenditures	-0.115	-0.100	-0.099	-0.114	-0.118
Investment Efficiency	-0.227	-0.485	-0.003	-0.211	-0.132
Cost Push	-0.196	-0.238	-0.167	-0.196	-0.211
Monetary Policy	-0.108	-0.108	-0.093	-0.108	-0.105
Wage Markup	-0.357	-0.135	-0.538	-0.361	-0.329
Preference	-0.187	-0.148	-0.176	-0.185	-0.198
Discretionary Fiscal Policy	-0.058	-0.059	-0.057	-0.058	-0.058
Std(y)	1.673	1.628	1.832	1.680	1.602
		Consumption Tax Model			
Technology	-0.038	-0.012	-0.048	-0.038	-0.040
Government Expenditures	-0.015	-0.010	-0.010	-0.015	-0.016
Investment Efficiency	-0.036	-0.109	0.012	-0.033	-0.032
Cost Push	-0.038	-0.047	-0.030	-0.038	-0.042
Monetary Policy	-0.013	-0.014	-0.010	-0.013	-0.013
Wage Markup	-0.079	-0.019	-0.127	-0.085	-0.076
Preference	-0.037	-0.027	-0.031	-0.033	-0.038
Discretionary Fiscal Policy	-0.006	-0.006	-0.006	-0.006	-0.006
Std(y)	1.624	1.617	1.733	1.630	1.557

Note: Average of Posterior Distribution of Elasticities.

3.2 Fiscal Policy Rule

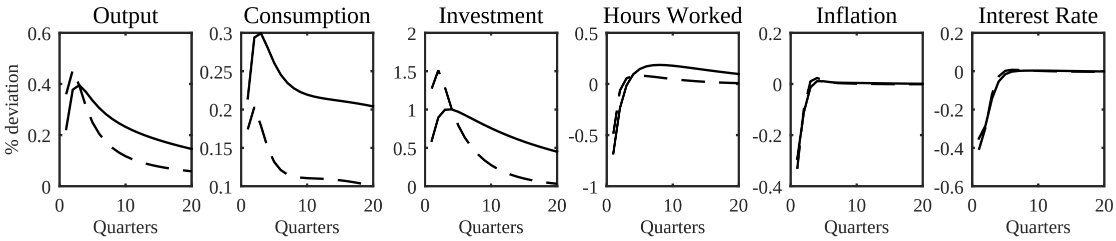
Table 2.17: Tax Elasticities of output (20 periods horizon): Varying Fiscal Policy

	Baseline	Output		Debt	
Shock	τ^w model	$\gamma_y = 0.50$	$\gamma_y = 1.00$	$\gamma_d = 0.1$	$\gamma_d = 1$
		Lump Sum Tax Model			
Technology	-0.038	-0.057	-0.005	-0.042	-0.057
Government Expenditures	-0.013	0.001	-0.035	-0.010	-0.026
Investment Efficiency	-0.028	-0.163	0.015	-0.008	-0.127
Cost Push	-0.042	-0.040	-0.043	-0.050	-0.042
Monetary Policy	-0.012	-0.010	-0.013	-0.015	-0.029
Wage Markup	-0.092	-0.147	-0.008	-0.097	-0.081
Preference	-0.037	-0.067	-0.034	-0.044	-0.053
Discretionary Fiscal Policy	0.000	-0.000	0.000	-0.000	-0.000
Std(y)	1.574	1.574	1.574	1.574	1.574
		Capital Tax Model			
Technology	-0.200	-0.236	-0.090	-0.200	-0.220
Government Expenditures	-0.115	-0.075	-0.181	-0.114	-0.149
Investment Efficiency	-0.227	-0.570	0.105	-0.138	-0.440
Cost Push	-0.196	-0.181	-0.210	-0.234	-0.177
Monetary Policy	-0.108	-0.100	-0.113	-0.129	-0.158
Wage Markup	-0.357	-0.514	-0.105	-0.395	-0.288
Preference	-0.187	-0.277	-0.186	-0.247	-0.204
Discretionary Fiscal Policy	-0.058	-0.058	-0.058	-0.061	-0.066
Std(y)	1.673	1.765	1.626	1.631	1.856
		Consumption Tax Model			
Technology	-0.038	-0.050	-0.009	-0.043	-0.047
Government Expenditures	-0.015	-0.005	-0.029	-0.015	-0.016
Investment Efficiency	-0.036	-0.149	0.008	-0.036	-0.100
Cost Push	-0.038	-0.036	-0.040	-0.046	-0.036
Monetary Policy	-0.013	-0.012	-0.015	-0.019	-0.021
Wage Markup	-0.079	-0.124	-0.008	-0.081	-0.067
Preference	-0.037	-0.060	-0.034	-0.046	-0.045
Discretionary Fiscal Policy	-0.006	-0.006	-0.006	-0.007	0.000
Std(y)	1.624	1.648	1.611	1.606	1.669

Note: Average of Posterior Distribution of Elasticities.

2.B.12 Endogenous Government Spending

Figure 2.26: Macroeconomic Aggregates: endogenous government spending (1 std.dev. Government Expenditures Shock)

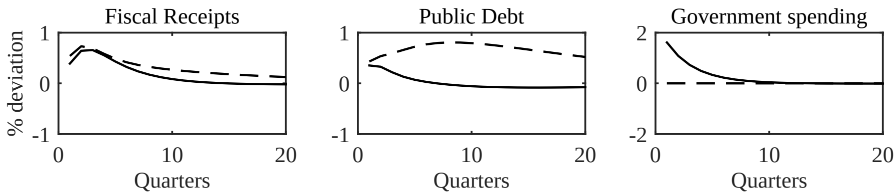


- - - - Baseline τ^w Model, —— endogenous g_t variant

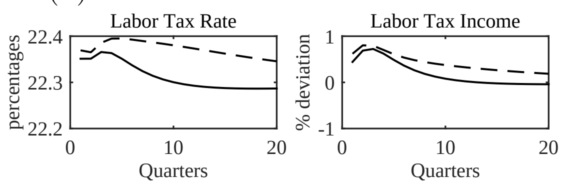
Note: Average of posterior distribution of IRFs.

Figure 2.27: Fiscal Policy: endogenous government spending (1 std.dev. Government Expenditures Shock)

(a) Debt and Tax Receipts



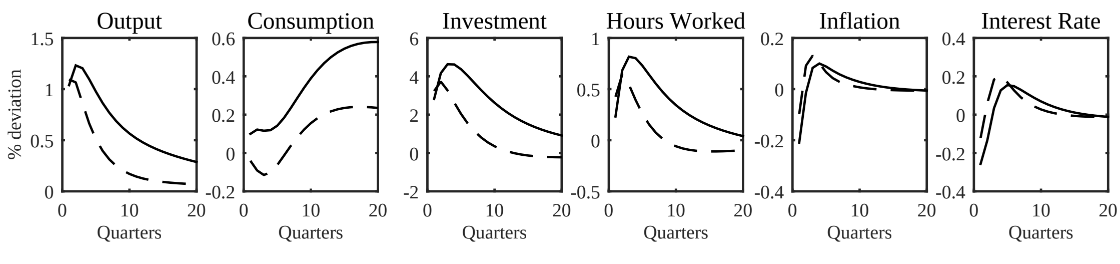
(b) Labor Tax Rates and Revenue



- - - - Baseline τ^w Model, —— endogenous g_t variant

Note: Average of posterior distribution of IRFs.

Figure 2.28: Macroeconomic Aggregates: endogenous government spending (1 std.dev. Investment Efficiency Shock)

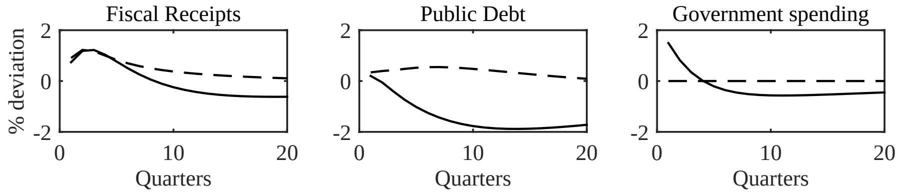


- - - - Baseline τ^w Model, —— endogenous g_t variant

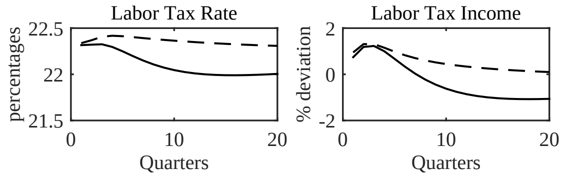
Note: Average of posterior distribution of IRFs.

Figure 2.29: Fiscal Policy: endogenous government spending (1 std.dev. Investment Efficiency Shock)

(a) Debt and Tax Receipts



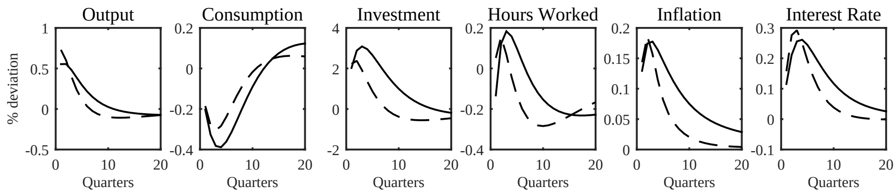
(b) Labor Tax Rates and Revenue



- - - - Baseline τ^w Model, —— endogenous g_t variant

Note: Average of posterior distribution of IRFs.

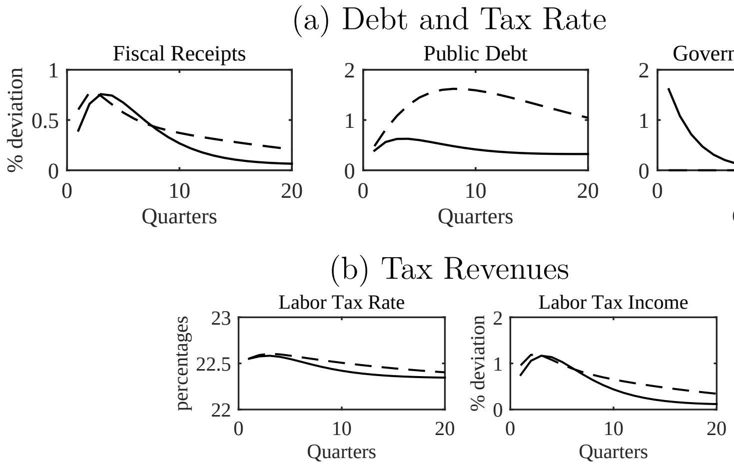
Figure 2.30: Macroeconomic Aggregates: Varying Government Spending Rule (1 std.dev. Cost Push Shock)



- - - - Exogenous government spending rule (benchmark) —— Endogenous government spending rule.

Note: IRFs are evaluated at the mean of the posterior distribution.

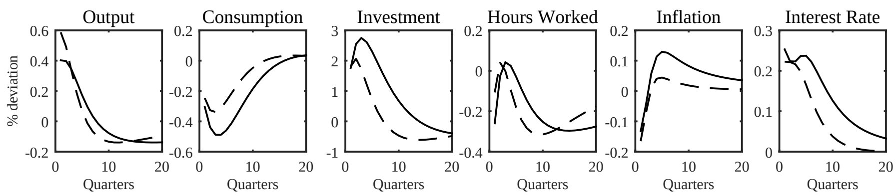
Figure 2.31: Fiscal Policy: Varying Government Spending Rule (1 std.dev. Cost Push Shock)



---- Exogenous government spending rule (benchmark) —— Endogenous government spending rule.

Note: IRFs are evaluated at the mean of the posterior distribution.

Figure 2.32: Macroeconomic Aggregates: Varying Government Spending Rule (1 std.dev. Monetary Policy Shock)

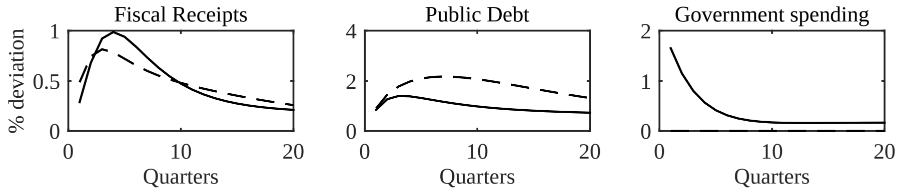


---- Exogenous government spending rule (benchmark) —— Endogenous government spending rule.

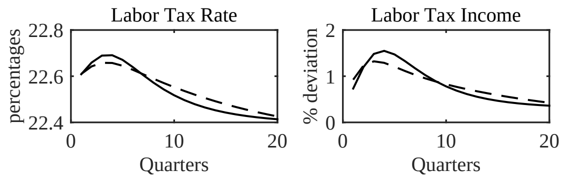
Note: IRFs are evaluated at the mean of the posterior distribution.

Figure 2.33: Fiscal Policy: Varying Government Spending Rule (1 std.dev. Monetary Policy Shock)

(a) Debt and Tax Rate



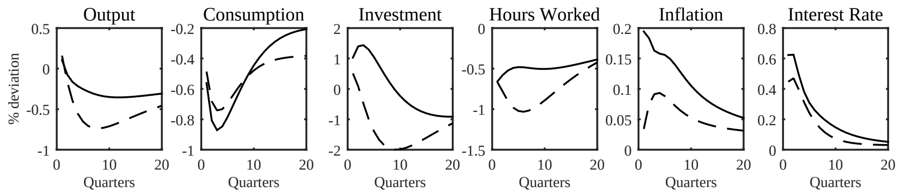
(b) Tax Revenues



- - - - Exogenous government spending rule (benchmark) —— Endogenous government spending rule.

Note: IRFs are evaluated at the mean of the posterior distribution.

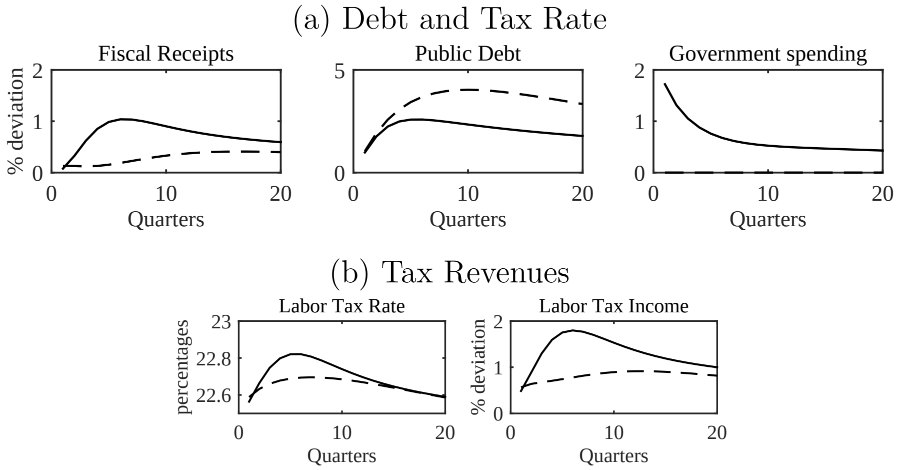
Figure 2.34: Macroeconomic Aggregates: Varying Government Spending Rule (1 std.dev. Wage Markup Shock)



- - - - Exogenous government spending rule (benchmark) —— Endogenous government spending rule.

Note: IRFs are evaluated at the mean of the posterior distribution.

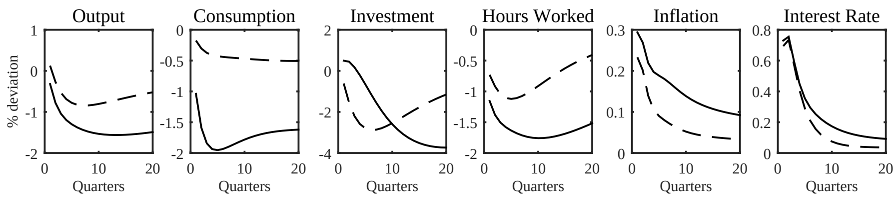
Figure 2.35: Fiscal Policy: Varying Government Spending Rule (1 std.dev. Wage Markup Shock)



- - - - Exogenous government spending rule (benchmark) —— Endogenous government spending rule.

Note: IRFs are evaluated at the mean of the posterior distribution.

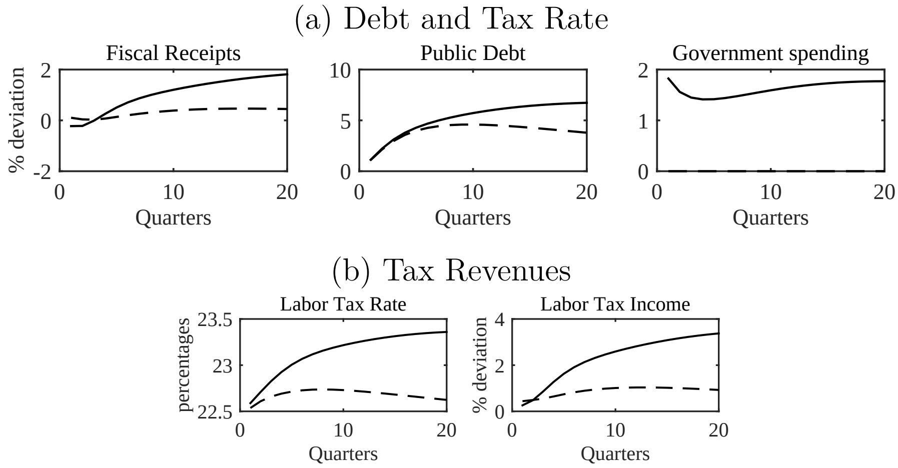
Figure 2.36: Macroeconomic Aggregates: Varying Government Spending Rule (1 std.dev. Preference Shock)



- - - - Exogenous government spending rule (benchmark) —— Endogenous government spending rule.

Note: IRFs are evaluated at the mean of the posterior distribution.

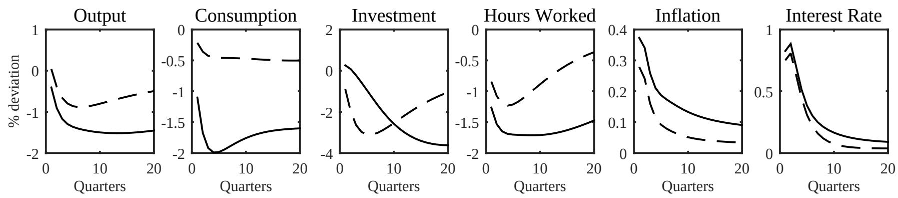
Figure 2.37: Fiscal Policy: Varying Government Spending Rule (1 std.dev. Preference Shock)



- - - - Exogenous government spending rule (benchmark) —— Endogenous government spending rule.

Note: IRFs are evaluated at the mean of the posterior distribution.

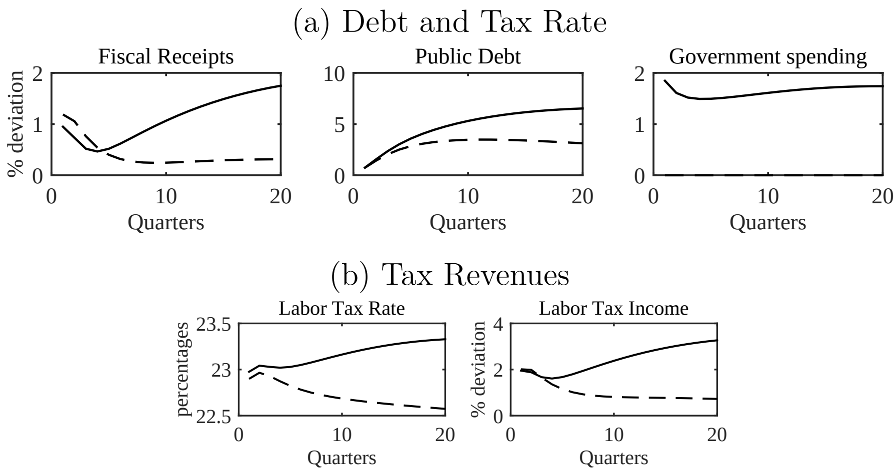
Figure 2.38: Macroeconomic Aggregates: Varying Government Spending Rule (1 std.dev. Discretionary Fiscal Policy Shock)



- - - - Exogenous government spending rule (benchmark) —— Endogenous government spending rule.

Note: IRFs are evaluated at the mean of the posterior distribution.

Figure 2.39: Fiscal Policy: Varying Government Spending Rule (1 std.dev. Discretionary Fiscal Policy Shock)



- - - - Exogenous government spending rule (benchmark) —— Endogenous government spending rule.

Note: IRFs are evaluated at the mean of the posterior distribution.

2.B.13 Absence of Wage Rigidities

Table 2.18: Posterior Results (Forcing Variables Processes)

	Priors			Posterior (Tax Model)			
	Distrib.	Mean	Std. Dev.	Lump Sum	Labor	Capital	Consumption
ρ_a	B	0.70	0.10	0.6374	0.6262	0.6668	0.6403
				[0.5993,0.6812]	[0.5873,0.6711]	[0.6314,0.7077]	[0.6018,0.6836]
ρ_g	B	0.70	0.10	0.7602	0.7516	0.7639	0.7640
				[0.7335,0.7965]	[0.7231,0.7881]	[0.7370,0.8003]	[0.7360,0.8001]
ρ_i	B	0.70	0.10	0.5564	0.5507	0.5717	0.5727
				[0.5199,0.5956]	[0.5144,0.5900]	[0.5368,0.6104]	[0.5365,0.6115]
ρ_p	B	0.70	0.10	0.8138	0.8184	0.8022	0.7963
				[0.7905,0.8480]	[0.7951,0.8554]	[0.7795,0.8366]	[0.7713,0.8329]
ρ_r	B	0.70	0.10	0.5014	0.4882	0.4971	0.5050
				[0.4546,0.5460]	[0.4411,0.5306]	[0.4498,0.5388]	[0.4582,0.5479]
ρ_h	B	0.70	0.10	0.9134	0.9190	0.9073	0.9158
				[0.9021,0.9318]	[0.9089,0.9362]	[0.8951,0.9279]	[0.9051,0.9348]
ρ_b	B	0.70	0.10	0.6071	0.6385	0.5918	0.5782
				[0.5700,0.6502]	[0.6029,0.6806]	[0.5555,0.6345]	[0.5406,0.6198]
ρ_f	B	0.70	0.10	0.7730	0.7683	0.7642	0.7690
				[0.7464,0.8103]	[0.7403,0.8088]	[0.7365,0.8021]	[0.7415,0.8072]
σ_a	IG	1.00	∞	0.6606	0.6657	0.6639	0.6641
				[0.6139,0.6919]	[0.6197,0.6951]	[0.6171,0.6953]	[0.6177,0.6936]
σ_g	IG	1.00	∞	1.9867	2.0060	1.9741	1.9951
				[1.8498,2.0708]	[1.8694,2.0955]	[1.8309,2.0630]	[1.8572,2.0843]
σ_i	IG	1.00	∞	1.7941	1.8979	1.7977	1.6445
				[1.6426,1.8950]	[1.7309,2.0023]	[1.6357,1.8961]	[1.4959,1.7357]
σ_p	IG	1.00	∞	0.6966	0.6827	0.7032	0.6910
				[0.6128,0.7405]	[0.5974,0.7275]	[0.6082,0.7410]	[0.6067,0.7360]
σ_r	IG	1.00	∞	0.4574	0.4525	0.4565	0.4563
				[0.4249,0.4776]	[0.4214,0.4734]	[0.4255,0.4774]	[0.4265,0.4770]
σ_h	IG	1.00	∞	1.6084	2.1789	1.5901	1.8294
				[1.3921,1.6980]	[1.8462,2.3070]	[1.3797,1.6838]	[1.5932,1.9432]
σ_b	IG	1.00	∞	1.2249	1.2145	1.2966	1.4065
				[1.1320,1.2837]	[1.1162,1.2716]	[1.2003,1.3623]	[1.2938,1.4808]
σ_f	IG	1.00	∞	1.1045	1.1754	1.1744	1.1035
				[1.0088,1.1619]	[1.0733,1.2409]	[1.0764,1.2411]	[1.0068,1.1616]

<u>Note</u>: B: Beta distribution, IG: Gamma Inverse distribution. 66% HPDI into brackets.

Table 2.19: Posterior Results (Structural Parameters)

	Priors			Posterior (Tax Model)			
	Distrib.	Mean	Std. Dev.	Lump Sum	Labor	Capital	Consumption
ρ_R	B	0.75	0.10	0.3996	0.4092	0.3995	0.4043
				[0.3666,0.4322]	[0.3752,0.4421]	[0.3665,0.4316]	[0.3716,0.4373]
κ_π	G	1.50	0.25	2.2322	2.1528	2.2327	2.2533
				[2.1056,2.3379]	[2.0315,2.2616]	[2.1033,2.3435]	[2.1218,2.3604]
κ_y	G	0.12	0.05	0.0988	0.0992	0.0983	0.1037
				[0.0771,0.1112]	[0.0765,0.1113]	[0.0768,0.1115]	[0.0808,0.1168]
ρ_f	B	0.50	0.20	0.3651	0.2803	0.3118	0.3714
				[0.3148,0.4197]	[0.2278,0.3261]	[0.2610,0.3595]	[0.3218,0.4226]
γ_y	N	0.50	0.25	0.7397	0.8568	0.8361	0.7744
				[0.6650,0.8157]	[0.7862,0.9281]	[0.7591,0.9122]	[0.7023,0.8445]
γ_d	N	0.50	0.25	0.1924	0.2168	0.1916	0.1843
				[0.1499,0.2236]	[0.1733,0.2496]	[0.1435,0.2210]	[0.1418,0.2126]
ξ_π	B	0.50	0.10	0.6421	0.6352	0.6403	0.6417
				[0.6220,0.6616]	[0.6153,0.6570]	[0.6194,0.6609]	[0.6218,0.6617]
ν_π	B	0.50	0.15	0.4090	0.4059	0.4048	0.4087
				[0.3346,0.4682]	[0.3316,0.4674]	[0.3295,0.4673]	[0.3310,0.4664]
ϕ	G	4.00	1.50	0.9537	1.3277	0.9405	1.0518
				[0.7570,1.0424]	[1.0321,1.4462]	[0.7513,1.0296]	[0.8316,1.1638]
b	B	0.50	0.20	0.7412	0.7313	0.7721	0.7397
				[0.7010,0.7926]	[0.6912,0.7816]	[0.7355,0.8187]	[0.6992,0.7892]
ν	G	2.00	0.75	2.0084	1.9802	2.0172	2.0233
				[1.6173,2.2463]	[1.6028,2.2253]	[1.6175,2.2619]	[1.6337,2.2643]
ψ	B	0.50	0.20	0.4917	0.4945	0.5019	0.4962
				[0.3955,0.5867]	[0.3996,0.5906]	[0.4066,0.5992]	[0.4010,0.5885]
Log–Likelihood				-158.1269	-158.5828	-157.6207	-162.5627

Note: B: Beta distribution, G: Gamma distribution, N: Normal distribution. 66% HPDI into brackets.

Table 2.20: Second Order Moments (Main aggregates)

Var.	Lump-sum	τ^w Model	τ_k Model	τ_c Model
Volatilities				
y	1.32	1.36	1.49	1.36
c	0.70	0.72	0.67	0.75
i	4.85	4.86	5.20	5.05
h	1.29	1.35	1.33	1.33
π	0.83	0.80	0.81	0.85
R	1.06	1.02	1.05	1.09
F	2.41	2.23	2.14	2.40
D	3.88	3.68	3.74	3.96
T	24.52	–	–	–
τ_w	–	3.23	–	–
τ_k	–	–	7.24	–
τ_c	–	–	–	29.83
T_w	1.96	2.90	2.11	2.00
T_k	1.96	1.97	6.36	2.00
T_c	0.70	0.72	0.67	29.58
Correlation with Output				
c	0.32	0.37	0.29	0.34
i	0.82	0.83	0.82	0.81
h	0.70	0.72	0.72	0.71
π	-0.07	-0.08	-0.05	-0.06
R	-0.27	-0.29	-0.24	-0.27
F	0.51	0.44	0.41	0.50
D	-0.32	-0.35	-0.41	-0.35
T	-0.16	–	–	–
τ_w	–	-0.31	–	–
τ_k	–	–	-0.42	–
τ_c	–	–	–	-0.20
T_w	0.81	0.22	0.86	0.82
T_k	0.81	0.84	-0.19	0.82
T_c	0.32	0.37	0.29	-0.19

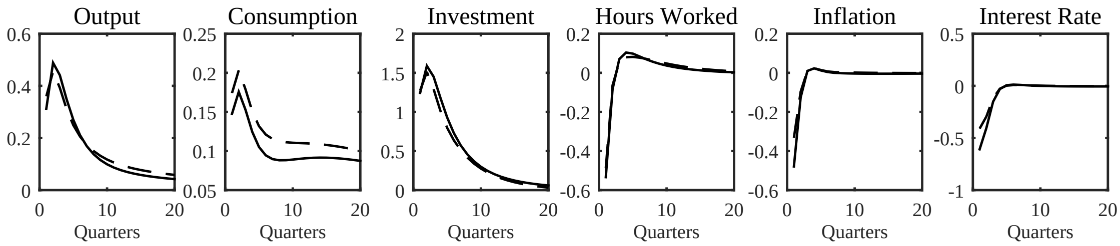
Note: Average of the posterior distribution of HP filtered moments ($\lambda = 1600$).

Table 2.21: Variance Decomposition of output: Nominal Price Rigidities

	a_t	g_t	ε_t^i	ε_t^p	ε_t^R	ε_t^w	ε_t^b	ε_t^f
Labor Tax Model: Benchmark								
1	16.43	12.79	27.18	16.46	2.60	22.25	1.32	0.98
4	15.00	2.78	20.58	18.12	1.03	39.40	1.80	1.28
8	11.80	1.96	16.11	18.05	0.76	48.37	1.97	0.99
20	9.09	2.32	12.59	17.37	0.61	55.09	2.18	0.74
Labor Tax Model: Absent Nominal Wage Rigidity								
1	19.96	19.70	12.55	23.33	2.13	20.53	0.61	1.18
4	24.14	4.10	7.09	24.23	0.65	37.02	1.28	1.50
8	19.27	3.03	5.11	23.56	0.47	46.13	1.29	1.14
20	14.79	3.11	3.91	21.18	0.38	54.44	1.30	0.88

Note: Variance Decomposition are evaluated at the posterior mean of the distribution.

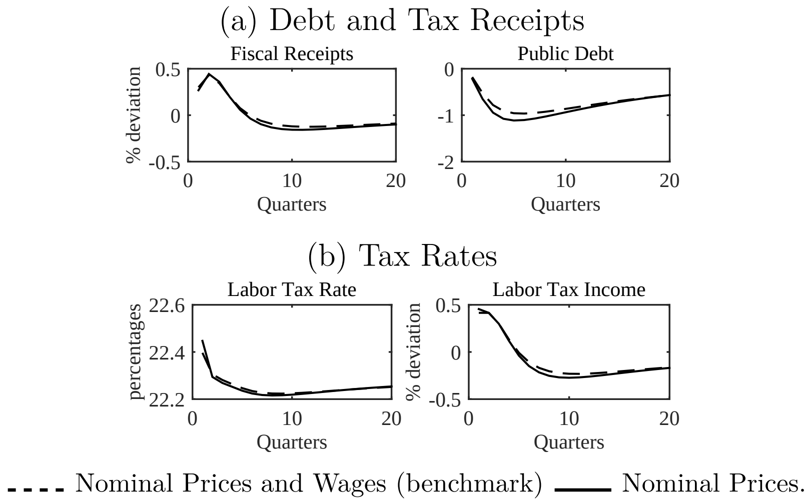
Figure 2.40: Macroeconomic Aggregates (Price Rigidity) (1 std.dev. Technology Shock)



- - - - Nominal Prices and Wages (benchmark) —— Nominal Prices.

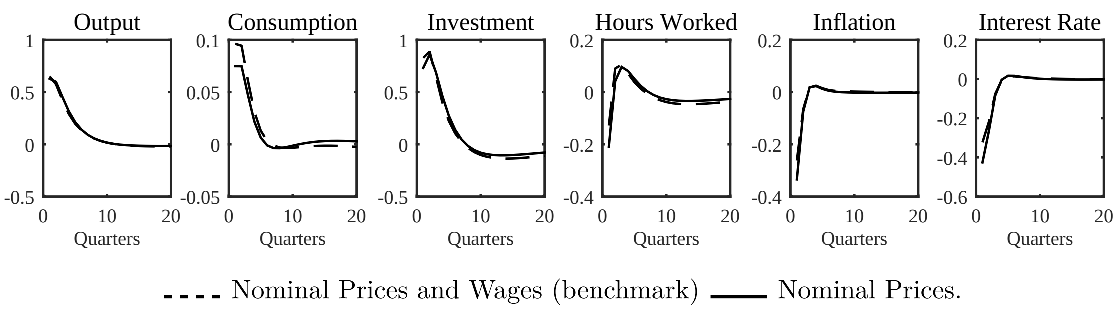
Note: IRFs are evaluated at the mean of the posterior distribution.

Figure 2.41: Fiscal Policy (Price Rigidity) (1 std.dev. Technology Shock)



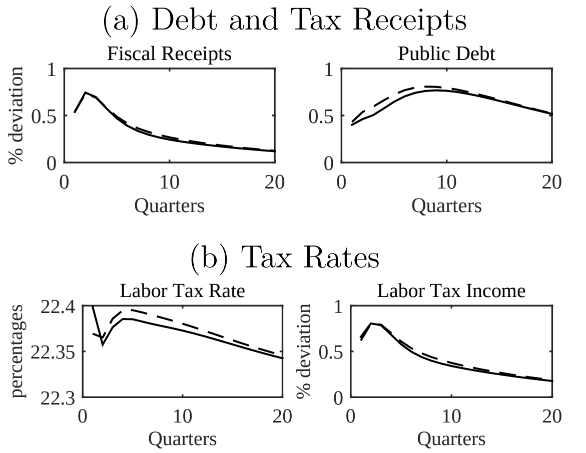
Note: IRFs are evaluated at the mean of the posterior distribution.

Figure 2.42: Macroeconomic Aggregates (Price Rigidity) (1 std.dev. Government Expenditures Shock)



Note: IRFs are evaluated at the mean of the posterior distribution.

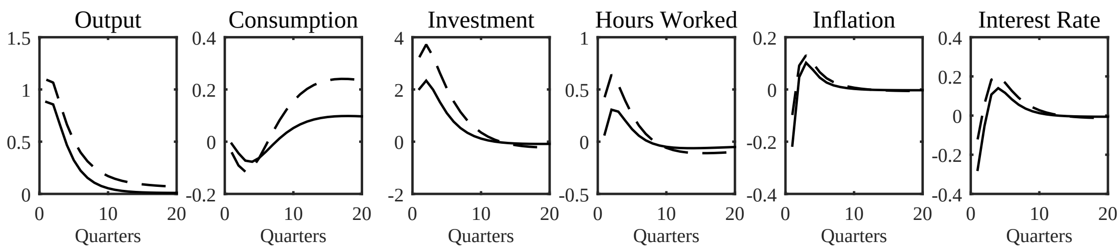
Figure 2.43: Fiscal Policy (Price Rigidity) (1 std.dev. Government Expenditures Shock)



---- Nominal Prices and Wages (benchmark) —— Nominal Prices.

Note: IRFs are evaluated at the mean of the posterior distribution.

Figure 2.44: Macroeconomic Aggregates (Price Rigidity) (1 std.dev. Investment Efficiency Shock)

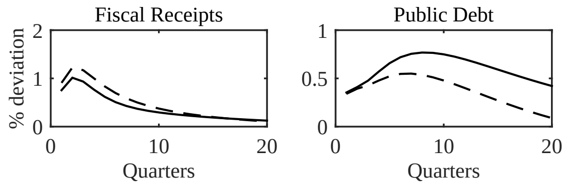


---- Nominal Prices and Wages (benchmark) —— Nominal Prices.

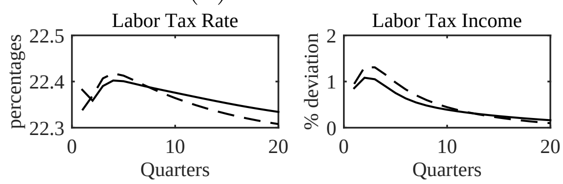
Note: IRFs are evaluated at the mean of the posterior distribution.

Figure 2.45: Fiscal Policy (Price Rigidity) (1 std.dev. Investment Efficiency Shock)

(a) Debt and Tax Receipts



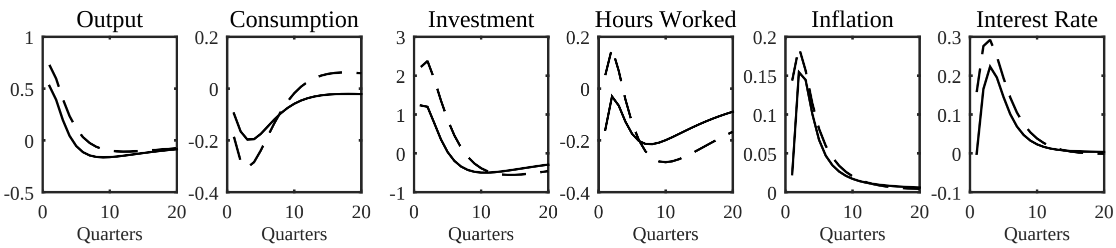
(b) Tax Rates



- - - - Nominal Prices and Wages (benchmark) ——— Nominal Prices.

Note: IRFs are evaluated at the mean of the posterior distribution.

Figure 2.46: Macroeconomic Aggregates (Price Rigidity) (1 std.dev. Cost Push Shock)

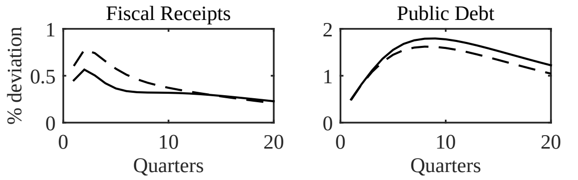


- - - - Nominal Prices and Wages (benchmark) ——— Nominal Prices.

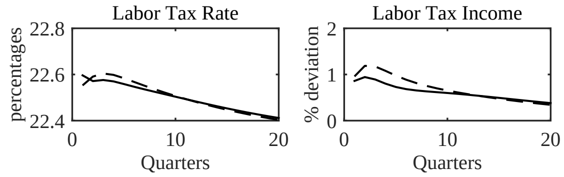
Note: IRFs are evaluated at the mean of the posterior distribution.

Figure 2.47: Fiscal Policy (Price Rigidity) (1 std.dev. Cost Push Shock)

(a) Debt and Tax Receipts



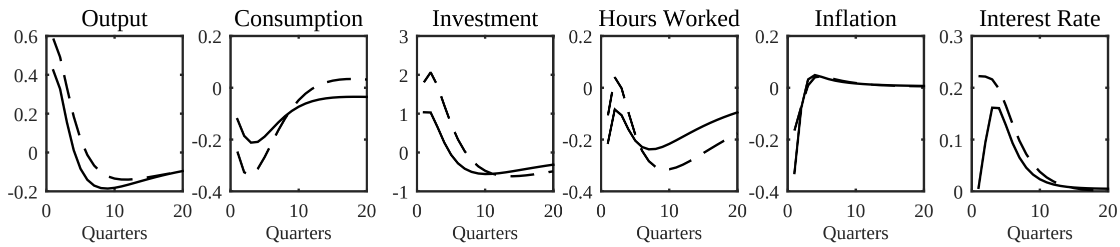
(b) Tax Rates



- - - - Nominal Prices and Wages (benchmark) —— Nominal Prices.

Note: IRFs are evaluated at the mean of the posterior distribution.

Figure 2.48: Macroeconomic Aggregates (Price Rigidity) (1 std.dev. Monetary Policy Shock)

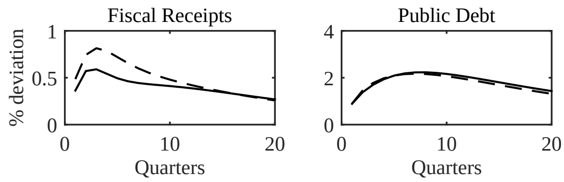


- - - - Nominal Prices and Wages (benchmark) —— Nominal Prices.

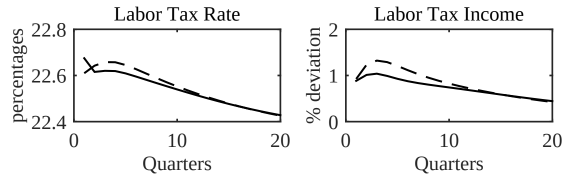
Note: IRFs are evaluated at the mean of the posterior distribution.

Figure 2.49: Fiscal Policy (Price Rigidity) (1 std.dev. Monetary Policy Shock)

(a) Debt and Tax Receipts



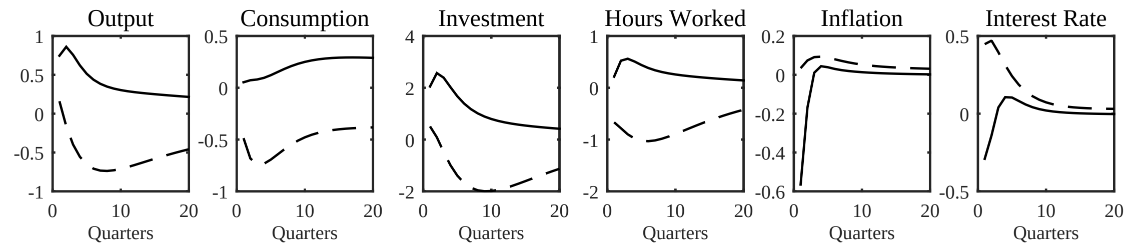
(b) Tax Rates



- - - - Nominal Prices and Wages (benchmark) —— Nominal Prices.

Note: IRFs are evaluated at the mean of the posterior distribution.

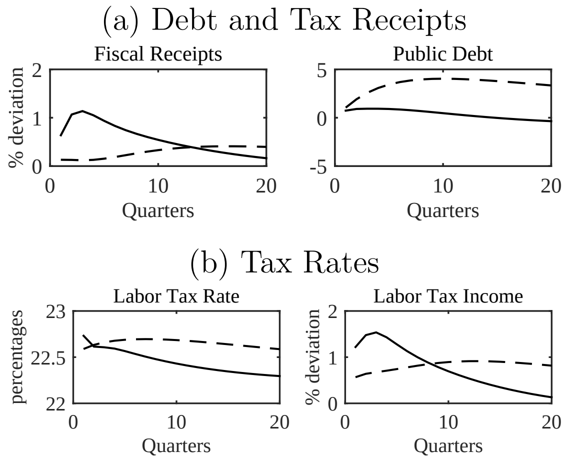
Figure 2.50: Macroeconomic Aggregates (Price Rigidity) (1 std.dev. Wage Markup Shock)



- - - - Nominal Prices and Wages (benchmark) —— Nominal Prices.

Note: IRFs are evaluated at the mean of the posterior distribution.

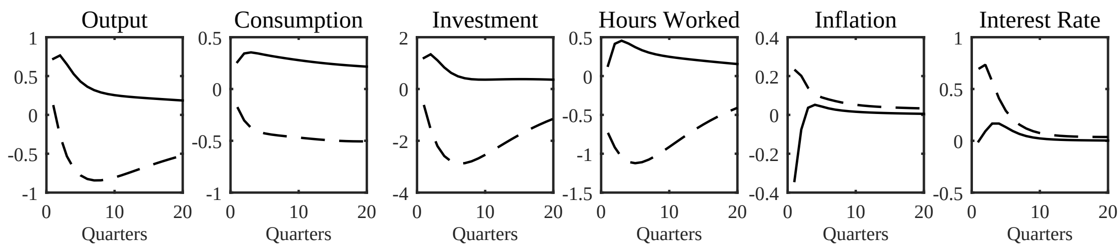
Figure 2.51: Fiscal Policy (Price Rigidity) (1 std.dev. Wage Markup Shock)



- - - - Nominal Prices and Wages (benchmark) —— Nominal Prices.

Note: IRFs are evaluated at the mean of the posterior distribution.

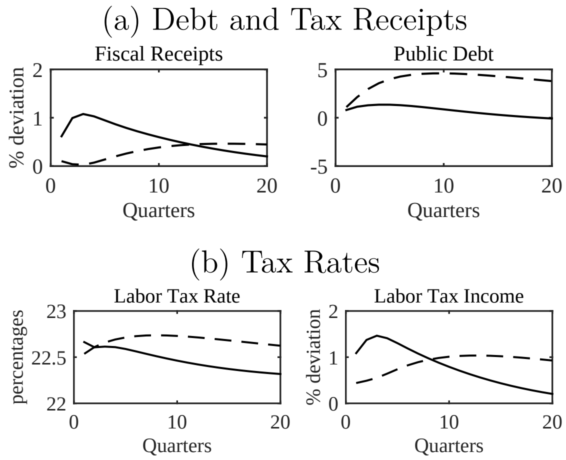
Figure 2.52: Macroeconomic Aggregates (Price Rigidity) (1 std.dev. Preference Shock)



- - - - Nominal Prices and Wages (benchmark) —— Nominal Prices.

Note: IRFs are evaluated at the mean of the posterior distribution.

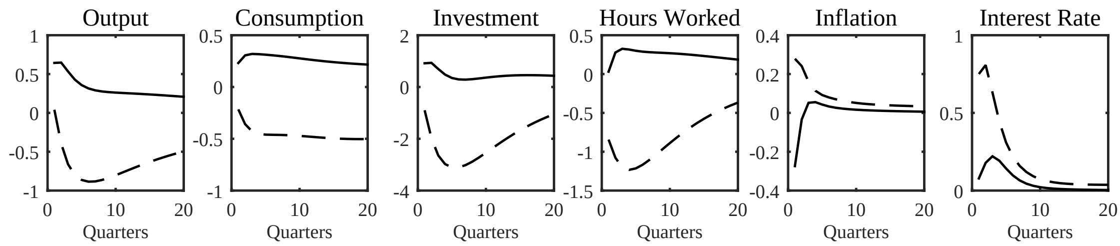
Figure 2.53: Fiscal Policy (Price Rigidity) (1 std.dev. Preference Shock)



---- Nominal Prices and Wages (benchmark) —— Nominal Prices.

Note: IRFs are evaluated at the mean of the posterior distribution.

Figure 2.54: Macroeconomic Aggregates (Price Rigidity) (1 std.dev. Discretionary Fiscal Policy Shock)

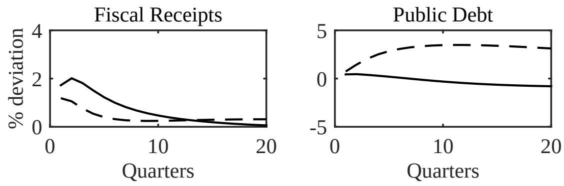


---- Nominal Prices and Wages (benchmark) —— Nominal Prices.

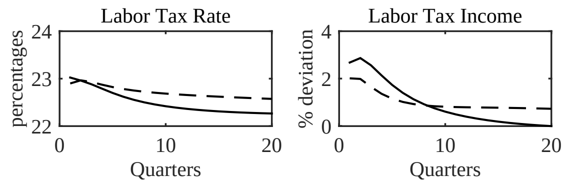
Note: IRFs are evaluated at the mean of the posterior distribution.

Figure 2.55: Fiscal Policy (Price Rigidity) (1 std.dev. Discretionary Fiscal Policy Shock)

(a) Debt and Tax Receipts



(b) Tax Rates



- - - - Nominal Prices and Wages (benchmark) —— Nominal Prices.

Note: IRFs are evaluated at the mean of the posterior distribution.

Chapter 3

Fiscal Consolidation and Employment Loss

3.1 Introduction

The recent sovereign debt crisis has brought back fiscal consolidation in the policy debate. Between 2004 and 2012 the sovereign debt to GDP ratio has increased around 35 percentage points for France, Greece, and United States; and for countries like Portugal and United Kingdom this increase has been around 60 percentage points (see Table 3.1). Such high levels of public debt are not without consequences for these economies in particular in terms of growth (see Reinhart and Rogoff (2010)). Governments in most advanced economies have acknowledged the problem and have been making efforts to design and implement fiscal consolidation plans in an attempt to reduce public debt. These plans have been implemented via either a reduction in government expenditure or by increasing the tax rates (either labor, consumption, or capital tax rates).

There exists a sizable literature that studies that effect of fiscal consolidation on the economy (e.g. Perotti (1996), Alesina, Favero, and Giavazzi (2014), among others). This literature has shown that the effects of fiscal consolidation episodes on output vary a lot with the fiscal instrument used to achieve the fiscal consolidation, the timing, the speed and the size of the consolidation. The type of the consolidation

Table 3.1: Sovereign debt (% of GDP)

	France	Greece	Iceland	Italy	Portugal	Spain	UK	US
2004	71.4	128.1	50.4	110.6	67.4	41.7	43.5	56.4
2012	103.8	164.3	117.5	131.1	126.2	67.6	103.2	93.8
Change	32.4	36.2	67.1	20.5	58.8	25.9	59.7	37.4

Source: The World Bank, World Development Indicators. Note: Changes in ratio are expressed in percentage point.

plan also plays a role. While the output loss and the associated sacrifice ratio have been extensively analyzed, the effect of fiscal consolidation episodes on employment remains largely unaddressed in the literature. This is however interesting for at least two main reasons. First, since most of the countries that undergo a fiscal consolidation experience high and persistent unemployment rates (*e.g.* Spain, Italy, France,...), it is then critical to evaluate *(i)* the potential employment loss (rise in unemployment) associated with the effort required to achieve the debt reduction and *(ii)* the persistence of this loss. Second, countries in which unemployment is still at a low level may also need to evaluate the potential output loss for monetary policy considerations. For instance, on September, 17, 2014, the FOMC re-affirmed the existence of an "FOMC's objective of maximum sustainable employment", which, in the context of fiscal consolidation, makes it critical to evaluate employment losses for the conduct of monetary policy. The objective of this paper is therefore to offer a minimal theoretical framework –a dynamic general equilibrium model– that allows to evaluate the employment loss associated with debt reduction plans.

This paper is related to the literature that studies fiscal consolidation within DSGE models. In particular, it relates to the seminal paper by Erceg and Lindé (2012) which investigated to what extent and how fiscal consolidation can harm output in a monetary union. In their setting, given the constraints imposed by monetary union and the focus of the central bank on area wide aggregate, monetary policy cannot accommodate the fiscal consolidation. In this setting, they find that an expenditure-based consolidation depresses output by more than a tax-based consolidation for several years. They also show that the "optimal strategy"—in terms of minimization of sacrifice ratio— is to mix sharp–temporary tax raise with gradual spending costs. The present paper builds upon their analysis, in particular in terms of the design of the fiscal consolidation process. It however fundamentally departs from their analysis in two important ways. First of all, I consider a real closed economy as my benchmark setting. The closed economy setting allows for a clear understanding of the mechanism at work by building intuition from a much more stylized model. By considering a real economy, I initially abstract from any interplay between monetary and fiscal policy, thereby isolating the mere fiscal mechanisms. I however also consider, as a sensitivity analysis, a nominal version of the model which enables to retrieve the interplay between the two types of policies. A second important point of departure from their analysis lies in the fact that the labor market of the economy considered in this paper features search and matching frictions. The existence of frictions in the labor market permits to study employment dynamics and to derive a measure of employment loss associated with fiscal consolidation episodes. In that respect, this paper is also related to the paper by Pappa, Sajedi, and Vella (2015), who also analyzes the effects of fiscal consolidation episodes within a DSGE model featuring labor market frictions. However, their analysis focuses on the role of rent seeking and tax evasion during spending cuts and tax hikes episodes more so than evaluating the role of labor market frictions. Doing so their analysis is relevant for Southern countries in which these phenomena prevail.

The model builds upon the textbook neoclassical growth model extended to *(i)* the presence of public debt and *(ii)* the existence of search and matching frictions à la Mortensen and Pissarides (1994) and Shimer and Rogerson (2010) on the labor market. The motivations for these two basic assumptions are grounded in the question addressed in this paper: the evaluation of employment (and output) loss generated by fiscal consolidation. There are several ways of generating (un)employment fluctuations in a general equilibrium framework (gift exchange, shirking, implicit contracts, search...); in this paper, I follow Merz (1995), Andolfatto (1996) Fève and Langot (1996) by integrating this search and matching setup in a general equilibrium model to explain the cyclical behavior in wages and employment fluctuations. Within this framework, the matching of workers and firms is costly, which results in a surplus for existing jobs and a bargaining situation over the wage. The model is otherwise standard.

Following Erceg and Lindé (2012), the government aims at reducing its debt to output ratio. It is reasonable to assume that policymakers would reduce the debt target gradually to help avoid potentially large adverse consequences on output. The main experiment assumes an initial 100% debt/GDP level which is then gradually reduced to 75%, which, thus, reflects 25% reduction in *desired* debt target –debt to output ratio. Its implementation is reached by adjusting the fiscal revenue to keep both the debt to output and deficit close to its target path. This is captured by a simple fiscal rule that fiscal authority abides by. The fiscal revenue adjustments are administered through the distortionary time varying taxation. In the baseline experiment, only the labor tax rate is allowed to adjust and government spendings are kept constant over time. Given that the model does not consider stochastic shocks, the model is solved under perfect foresight, and all potential non-linearities affecting the adjustment dynamics are preserved. Later, the model is also extended to incorporate nominal rigidities. Specifically, it integrates price stickiness and a standard Taylor rule allowing for a potential interaction between fiscal and monetary policies.

The fiscal austerity is accompanied by a recession in an attempt to achieve the debt reduction objective. Thus, both employment and output decrease. At the trough of the recession (4.5 years following the beginning of the adjustment), output is 1.5% below its initial steady state. In the benchmark experiment, the initial unemployment rate is 5.5% and it climbs up to 7.3% after 3.35 years following the commencement of fiscal consolidation. Thus, at its peak the employment loss reaches 1.9 percentage points in deviations from its steady state. The employment losses are persistent and lasting on average 12 years.

The mechanism at work is as follows. A debt reduction requires that tax revenue increase in order to finance the constant flow of government expenditures. The government substitutes debt for tax revenues, therefore creating a negative wealth effect on the agents. As will become clear later, the presence of the negative wealth effect will lead to a decrease in consumption and investment –and therefore capital accumulation– which will affect negatively the tax base. Tax rates have to adjust. Given that both the consumption tax, the capital income tax and lump sum taxes are held constant, the labor tax has to increase to permit the increase in the tax revenues. The tax increases from 25% to about 30% at the peak. As the debt reduction process approaches completion, the effort in debt reduction is compensated by a reduction in debt services. Tax revenues can then be lowered, which translates eventually into a reduction in the labor tax that eventually reaches a lower level of 23.8%.

Higher labor tax rate, then, leads to an increase in the wage. This reflects the fact that the household uses the Nash bargaining process to be compensated for the increase in the tax burden. The increase in the wage reduces the marginal value of employment for the firm, which then cut on their vacancy postings. This therefore increases unemployment, and its duration. Hence the persistent drop in employment in the economy.

Over the whole adjustment (from period t to ∞), the cumulative output losses amount to 13% (the discounted cumulative losses are 17%, given the discount factor of household), meaning that the short–run losses outweigh the long run gains. On the other hand, the employment experiences cumulative gains amounting to 9%. As the beneficial effects of fiscal consolidation kick in, the losses do recede. However, it takes 58 years for the cumulative output losses to cancel out and eventually turn into gains, 45 years for employment. This points to the existence of an intertemporal trade-off between the long–run gains of debt reduction on the one hand, and the short–run employment and output losses generated by fiscal consolidation. In a nutshell, the main results reveal that fiscal consolidation episodes are costly in the short to medium run, both in terms of output and in terms of employment. Thus, households have to be patient enough to experience the gains associated to such policies.

The robustness of these findings are then assessed to alternative settings for the consolidation policy. In particular, the sensitivity to the state of the business cycle, the speed and size of the debt reduction, the presence of alternative instruments (government spendings, and other taxes) and the timing of the consolidation are investigated. The robustness analysis shows the losses tend to be higher during recessions due to the opposing demands placed on the labor tax adjustment by *(i)* fiscal consolidation and *(ii)* output stabilization. Faster debt consolidation comes at the cost of a bigger initial adjustment which magnifies the employment loss in the short–run. A slower adjustment allows for smooth debt adjustment that limits the initial employment loss, but in that case it lasts longer and the economy, thus, suffers longer. Moreover, the paper shows that endogenous government spending, the type of tax instrument used to achieve fiscal adjustment, and expected future debt reduction also matter. Finally, the interplay between fiscal and monetary policy is analyzed. The monetary policy is non neutral and it affects the fiscal consolidation process. The central bank by adjusting the nominal interest rate affects debt services and therefore calls for an adjustment of the tax. This aids the whole debt reduction process and, thus, speeds up the fiscal consolidation in the short–run. But, by hindering demand, it magnifies the output and employment losses.

The plan of the paper is as follows. Section 2 presents the benchmark real model. Section 3 details the model calibration. Section 4 investigates the implications of fiscal consolidation in terms of output and employment loss and sheds light on the main mechanisms at work in the model. Section 5 conducts a sensitivity analysis of the results to changes in the way the fiscal consolidation is achieved. In particular, I investigate how the choice of the fiscal instruments, the timing, the size of the debt reduction matter. I also study how sensitive are the results to the state of the business cycle. Section 6 extends the model to the presence of nominal rigidities, thereby allowing to address the interplay between fiscal and monetary policies. In this section the sensitivity analysis for a nominal economy is performed: it studies the nominal aspect for an alternative fiscal instrument –consumption tax–, the degree of price rigidity, and the responsiveness of central bank to output fluctuations and price stabilization. A last section offers concluding remarks.

3.2 Model

This section presents a standard neoclassical model extended to *(i)* the presence of public debt and *(ii)* the existence of search and matching frictions à la Mortensen and Pissarides (1994) and Shimer and Rogerson (2010) on the labor market. The motivation for these two assumptions is grounded in the question addressed in this paper: the evaluation of the employment (and output) loss generated by fiscal consolidation. Given that the fiscal consolidation considered in this paper takes the form of a reduction in the sovereign debt to output ratio, the model includes public debt. Given that we are interested in the effects on (un)employment, the model shall feature a motive for the existence of unemployment. There are several ways of generating (un)employment fluctuations within a general equilibrium framework (gift exchange, shirking, implicit contracts, search...); In this paper, I follow Merz (1995), Andolfatto (1996) Fève and Langot (1996) who showed, within alternative frameworks, how search and matching frictions provide a fairly good representation of unemployment fluctuations over the business cycle. The model is otherwise standard.

3.2.1 Labor Market Frictions

Following Mortensen and Pissarides (1994), we assume that trade on the labor market is costly and subject to coordination failures that are captured by the existence of search and matching frictions. There exists a continuum of mass 1 of individuals who, in each and every period, can be either employed (a fraction n_t) or unemployed ($u_t = 1 - n_t$). All individuals are assumed to possess the same skills and abilities, implying that their status on the labor market is not determined by their relative productivity, but by the outcome of a random search process. Given this ex-post heterogeneity across individuals, and given that these individuals will accumulate assets as a way to transfer wealth across periods, the wealth distribution in the economy is potentially a state variable. In order to avoid dealing with a distribution and face a typical Krusell and Smith's (1998) problem, we assume that all individuals are members of a single representative household and meet at the end of the period and pool resources –therefore implementing a perfect risk sharing environment. This way the only relevant state variable pertaining to wealth accumulation will be the level of assets, and not their distribution.

The existence of search and matching frictions on the labor market is captured by the existence of a matching function that relates the number of successful matches, M_t, to the number of unemployed, u_t, and the number of vacancies, v_t, posted by firms

$$M_t = m(u_t, v_t)$$

The function is strictly increasing, concave in both u_t and v_t and exhibits constant returns to scale.[1] Following Hagedorn and Manovskii (2008a), we use the following matching function

$$m(u_t, v_t) = \frac{v_t(1-n_t)}{(v_t^{\xi} + (1-n_t)^{\xi})^{1/\xi}} \tag{3.1}$$

where the matching function parameter is $\xi \in (0,1)$. The evolution of aggregate employment can then be described as follows. At the beginning of period t, n_t individuals are employed. During period t, M_t new matches are formed and add to the existing level of employment. Finally a constant fraction $\psi \in (0,1)$ of individuals separate from their employer. Hence, the level of employment available as of $t+1$ is given by

$$n_{t+1} = M_t + (1-\psi)n_t \tag{3.2}$$

Note that, because the matching function depends on aggregate quantities that are out of the control of the individuals, this equation captures all externalities at work in the search and matching process.

Consider the case of an individual looking for a job. Using the law of large numbers, this individual has a probability

$$s_t = \frac{M_t}{u_t} = \frac{m(u_t, v_t)}{u_t}$$

of finding a job. This individual faces two types of externalities. First she benefits from a positive trade externality created by firms: by posting more vacancies

[1] This assumption of constant returns to scale is consistent with the empirical findings reported by Blanchard and Diamond (1989) for US data and by Pissarides (1986) for UK data.

on the market, firms increase the probability that an individual will find a job ($\partial s_t/\partial v_t > 0$). Second, it suffers a congestion externality: when more individuals are searching, the probability of finding a job decreases ($\partial s_t/\partial u_t < 0$). Given the existence of constant returns to scale, the probability of finding a job can be rewritten

$$s_t = s(\theta_t)$$

where $\theta = v_t/u_t$ is a measure of labor market tightness. It should also be clear from the previous discussion that $s'(\cdot) > 0$.

Likewise, consider a firm posting v_t vacancies. Using the law of large numbers, the probability of filling a vacancy is given by

$$q_t = \frac{M_t}{v_t} = \frac{m(u_t, v_t)}{v_t}$$

As in the case of a single individual, each firm faces two types of externalities. First it benefits from a positive trade externality created by unemployed workers: The larger the pool of workers the firm faces, the larger the probability it will fill a vacancy ($\partial q_t/\partial u_t > 0$). Second, it also faces a congestion externality created by the other firms: by posting more vacancies on the market, firms increase the probability that an individual will find a job ($\partial s_t/\partial v_t > 0$). Second, it suffers from a congestion externality: the larger the number of aggregate vacancies the smaller the probability that each individual firm will fill its vacancy ($\partial q_t/\partial v_t < 0$). Note that this probability can also be expressed in terms of labor market tightness as $q_t = q(\theta_t)$ where $q'(\cdot) < 0$. In that context the employment level of firm j, $n_t(j)$, evolves as

$$n_{t+1}(j) = q_t v_t(j) + (1 - \psi)n_t(j) \tag{3.3}$$

The fact that q_t is beyond the control of the firm captures the existence of externalities.

3.2.2 Households

There exists a representative household who is composed of a continuum of individuals. At the beginning of period t, the members of the household visit the labor market. As explained in the previous section, a fraction n_t of these members are employed. These individuals supply inelastically 1 unit of labor. The complementary fraction is unemployed and performing search activities. At the end of the period, all these members go back to the household and pool their resources, therefore enabling perfect risk sharing. As explained in the previous section, this assumption simplifies our analysis as it allows us to ignore any distributional issue.[2] The household has preferences over consumption and leisure described by the following intertemporal utility function[3]

$$\sum_{t=0}^{\infty} \beta^t \left(\log c_t - \vartheta \frac{n_t^{1+\nu}}{1+\nu} \right) \tag{3.4}$$

where $\nu > 0$ and $\vartheta > 0$. c_t denotes the household's consumption and n_t is the fraction of employed household members, which is determined by the matching process and is beyond the control of the household.

The household enters a period with some initial financial wealth b_{t-1} that yields a gross real return r_{t-1}, earns a wage w_t per unit of labor, pays a proportional labor tax $\tau_t^w \in (0,1)$, such that the total after tax labor income is given by $(1-\tau_t^w)w_t n_t$. The household leases capital at the after–tax rental rate $(1-\tau_t^k)z_t$, where $\tau_t^k \in (0,1)$ denotes the capital income tax. Each member also receives a share of the profits of all firms, Π_t, and a lump–sum government transfer, T_t. This income is then used to consume, c_t (net of the consumption tax $\tau_t^c \in (0,1)$), invest, i_t, and purchase assets, b_t, as a way to transfer wealth towards next period. She therefore faces the

[2]An alternative way of dealing with this issue would be to create a perfect unemployment insurance market. At the beginning of the period, each household buys an insurance contract that insures her against labor market risk. Assuming that insurance companies are risk neutral, this insurance mechanism is perfect in the sense that be she employed or not the household would enjoy the same marginal utility of consumption. Therefore, all household would accumulate the same amount of assets, which then implies that the distribution of assets is irrelevant for the model solution.

[3]Implicit in this formulation of the utility is that the household's disutility of labor is determined by the disutility of the aggregate labor supplied by her members rather that the aggregation of the disutilities. This assumption is consistent with the fact that individuals pool resources within the household.

following budget constraint

$$(1+\tau_t^c)c_t + i_t + b_t = r_{t-1}b_{t-1} + (1-\tau_t^w)w_t n_t + (1-\tau_t^k)z_t k_t + \Pi_t + T_t \tag{3.5}$$

Investment, i_t leads to the formation of the capital stock, k_t, whose law of motion is described by

$$k_{t+1} = \left(1 - \phi\left(\frac{i_t}{i_{t-1}}\right)\right) i_t + (1-\delta)k_t \tag{3.6}$$

where $\delta \in (0,1)$ denotes the rate of depreciation of capital. Implicit in this formulation is that capital accumulation is subject to convex investment adjustment costs, $\phi(\cdot)$, à la Christiano, Eichenbaum, and Evans (2005a). These costs satisfy $\phi(1) = \phi'(1) = 0$, so that these costs are absent in the steady state, and $\varphi \equiv \phi''(1) > 0$. [4]

The household determines her consumption, investment and accumulation plans by maximizing her utility subject to her budget constraint (3.5), transition equation for capital (3.6), and given the perceived law of motion of employment (3.2) (which remains beyond her control at this stage of the problem). In doing so, a household takes as given prices, taxes and transfers, and aggregate quantities.

The household's optimal behavior is then characterized by the set of Euler conditions

$$\frac{1}{c_t(1+\tau_t^c)} = \beta \frac{r_t}{c_{t+1}(1+\tau_{t+1}^c)} \tag{3.7}$$

$$q_t^i = \beta \frac{c_t(1+\tau_t^c)}{c_{t+1}(1+\tau_{t+1}^c)}(z_{t+1}(1-\tau_{t+1}^k) + q_{t+1}^i(1-\delta)) \tag{3.8}$$

$$1 = q_t^i \left(1 - \phi\left(\frac{i_t}{i_{t-1}}\right) - \left(\frac{i_t}{i_{t-1}}\right)\phi'\left(\frac{i_t}{i_{t-1}}\right)\right) + \beta \frac{c_t}{c_{t+1}} q_{t+1}^i \phi'\left(\frac{i_{t+1}}{i_t}\right)\left(\frac{i_{t+1}}{i_t}\right)^2 \tag{3.9}$$

where q_t^i is the marginal Tobin's Q associated with the capital decision. Equation (3.7) is the standard consumption saving intertemporal arbitrage condition, which

[4]Note that for the quantitative analysis, the costs will take the form

$$\phi(x) = \frac{\varphi}{2}(x-1)^2$$

where $\varphi \in \mathbb{R}_+$ control for the size of the costs.

is just distorted by the presence of the consumption tax. Equation (3.8) describes the standard consumption investment tradeoff faced by the household. As in the case of the consumption savings decision, this arbitrage condition is also affected by the tax. The last equation describes the evolution of the marginal Tobin's Q, q_t^i, which differs from unity due to the presence of investment adjustment costs. The presence of potentially time varying taxes in the optimal decisions of the household highlights how fiscal consolidation will affect the economy.[5] Fiscal consolidation, in the form of a reduction of the debt to output ratio, requires the government to find alternative ways of financing its public expenditures. This will then require some adjustment in the tax rates, which will in turn affect the optimal consumption, investment and savings decisions of the household.

3.2.3 Firms

There exists a continuum of firms, indexed by $j \in (0, 1)$, which produce a homogenous good that can be either consumed or invested by means of capital and labor. The technology exhibits constant returns to scale and can be described by the Cobb–Douglas production function

$$y_t(j) = A_t k_t^{\alpha}(j) n_t(j)^{1-\alpha} \tag{3.10}$$

where $\alpha \in (0, 1)$. A_t denotes the total factor productivity of the firm, which sequence, $\{A_t\}_{t=0}^{\infty}$, is exogenously given. Note that given that firms all face the same technology and that there does not exist any idiosyncratic uncertainty, firms will be identical ex-post. Contrary to the standard neoclassical framework, the existence of labor market frictions implies that firms that enter in period t with employment $n_t(j)$ have to post vacancies $v_t(j)$ should it want to increase its level of employment in the next period. However posting a vacancy involves paying a constant unit cost $a > 0$. The firm has a probability q_t (beyond the control of the firm) of filling this vacancy, and faces a probability ψ that an employee separates. The law of motion of employment in firm j is therefore described by Equation

[5] As will become clear later, the wage faced by the household will also be affected by variations in a tax.

(3.3). The firm decides its production and vacancy posting plans by maximizing its intertemporal discounted profit

$$\max \sum_{t=0}^{\infty} \Psi_{0,t} \left(y_t(j) - z_t k_t(j) - w_t n_t(j) - a v_t(j) \right) \tag{3.11}$$

subject to the law of motion of employment, Equation (3.3). $\Psi_{0,t}$ denotes the discount factor of the firm between periods 0 and t. Given that, in the model, the interests of the manager of the firm are aligned with those of the shareholder –the household– the proper discount factor is given by $\Psi_{0,t} = \beta^t (1 + \tau_t^c) \frac{\partial U(c_t, n_t)}{\partial c_t}$.

The optimal production and vacancy posting plans are characterized by the following optimality conditions

$$z_t = \alpha \frac{y_t(j)}{k_t(j)} \tag{3.12}$$

$$\frac{a}{q_t} = \beta \frac{c_t(1 + \tau_t^c)}{c_{t+1}(1 + \tau_{t+1}^c)} \left((1 - \alpha) \frac{y_{t+1}(j)}{n_{t+1}(j)} - w_{t+1} + (1 - \psi) \frac{a}{q_{t+1}} \right) \tag{3.13}$$

The first condition is the standard demand for capital. The second condition determines the optimal vacancy posting behavior–and hence the optimal employment level. Firm j chooses the number of vacancies such that the marginal advertising costs equalizes the expected discounted future payoff. The expected payoff is conditional on the marginal vacancy leading to a match with probability q_t. The left hand side of (3.13) captures effective marginal hiring costs, which a firm trades off against the surplus over wage payments it can appropriate and against the benefit of not having to hire someone next period. Note that, in a symmetric equilibrium, it must therefore be the case that $x_t(j) = x_t(i) = x_t$, with $x \in \{k, n, v\}$.

3.2.4 Wage determination

The existence of labor frictions implies that there does not exist an auctioneer that would set the wages competitively. A mechanism to determine the wage must be specified. In this paper, I follow the literature (see e.g. Mortensen and Pissarides (1994), Merz (1995), Andolfatto (1996) among others) and assume that wages are determined as the outcome of a bilateral bargaining process between workers and firms. Since the workforce is homogeneous, each worker is marginal when bargaining with the firm. Both parties choose wage rates to maximize the joint surplus generated from their employment relationship: surpluses accruing to the matched parties are then split according to a Nash bargaining mechanism.

The surplus of a firm, Ω_t^F, is given by

$$\Omega_t^F = (1-\alpha)\frac{y_t}{n_t} - w_t + (1-\psi)\frac{a}{q_{t+1}}$$

and corresponds to the marginal value –expressed in terms of goods– of a match, which corresponds to the marginal product of employment net of the wage paid to the new hire, plus the marginal benefit of not having to hire a new worker in the next period.

The before tax surplus of the household, Ω_t^H, is given by the marginal utility value of a match, expressed in terms of goods by dividing by the marginal utility of consumption. The marginal utility value of a match can be found by comparing the options available to the worker. When the worker is employed, she contributes to the household value by earning a wage w_t, but suffers a disutility from working and forfeits an outside option payment X_t. This is weighted against next period's expected utility. The marginal utility value of a match is thus given by

$$\Omega_t^H = w_t - \frac{X_t}{1-\tau_t^w} - \frac{\vartheta c_t n_t^\nu}{1-\tau_t^w} + \beta\frac{(1+\tau_{t+1}^c)c_{t+1}}{(1+\tau_t^c)c_t}\frac{1-\tau_{t+1}^w}{1-\tau_t^w}\Omega_{t+1}^H(1-\psi-q_t\theta_t)$$

where I made use of the expression for the marginal utility of consumption, and the derivative of next period employment with respect to current employment.

The joint surplus, S_t, is then given by

$$S_t \equiv \Omega_t^{H\,\eta}\Omega_t^{F\,1-\eta} \tag{3.14}$$

where $\eta \in [0,1]$ represents the relative bargaining power of workers. The wage is then set so as to maximize the joint surplus, which leads to the surplus sharing

$$(1-\eta)\Omega_t^H = \eta\Omega_t^F$$

Substituting of the individual surplus values results, after tedious algebra, in the following wage setting rule:

$$w_t = \frac{\eta\left((1-\alpha)\frac{y_t}{n_t} + a\theta_t + (1-\psi)\frac{a}{q_t}\right) + (1-\eta)\left((1-\tau_t^w)X_t + \vartheta n_t^\nu c_t(1+\tau_t^c)\right)}{1-\tau_t^w(1-\eta)} \tag{3.15}$$

As is typical in models with surplus sharing, the wage is a weighted average of the payments accruing to workers and firms, with each party appropriating a fraction of the other's surplus. The bargained wage also includes mutual compensation for costs incurred, namely hiring costs and the utility cost of working. The bargaining weight determines how close the wage is to either the marginal product of labor or to the outside option of the worker, the latter of which has two components, unemployment benefits and the consumption utility of leisure. Note that the wage setting rule is fundamentally affected by the labor tax rate. It can be readily verified that as long as the worker's outside option X_t is smaller than the wage –which would be the case if the outside option is a fraction of the wage, like unemployment benefits– this function is increasing in the tax. It is then clear that should fiscal consolidation lead to an increase in the labor tax, as a way to substitute debt for tax revenues when financing public expenditures, this would put upward pressure on the bargained wage rate and will, in turn, reduce the labor demand and increase equilibrium unemployment. Likewise the consumption tax ought to have a similar effect, should it be used to financed public expenditures.

3.2.5 Fiscal policy and Debt adjustment

Fiscal authorities collect taxes (f_t) and issue public bonds (b_t) as a way to finance an exogenously given sequence of government spending $\{g_t\}_{t=0}^{\infty}$. Accordingly, the government budget constraint is given by

$$b_t = r_{t-1}b_{t-1} + g_t - f_t \tag{3.16}$$

Tax revenues, f_t, comprise consumption tax revenues, $\tau_t^c c_t$, labor tax revenues, $\tau_t^w w_t n_t$, capital tax revenues, $\tau_t^k z_t k_t$ and the lump–sum tax, T_t, such that

$$f_t = \tau_t^c c_t + \tau_t^w w_t n_t + \tau_t^k z_t k_t + T_t \tag{3.17}$$

Given this setting, I am now in a position to describe the fiscal consolidation process. Policymakers are assumed to use the proceeds from taxation to control the path of public debt. More precisely, let us denote $b_t^\star$ the target debt to output ratio, then the fiscal authorities set the tax revenues according to the simple rule

$$\log(f_t) = \log(\overline{f}) + \gamma_1 \left(\log\left(\frac{b_{t-1}}{y_t}\right) - \log(b_t^\star)\right) \tag{3.18}$$

where $\gamma_1 > 0$. This rule stipulates that any positive (negative) deviation of the debt/output ratio from its targeted value leads to an increase (decrease) in tax revenues that the government should collect ($\gamma_1 > 0$). That way the government substitute debt for tax revenues (and vice versa). Let us then consider the case where, initially, public debt is on target ($b_{t-1}/y_t = b_t^\star$), and assume that the targeted value of the debt/output ratio, $b_t^\star$, is shifted downward. As aforementioned, given that debt is predetermined, the debt/output gap increases leading to an upward adjustment of tax revenues. Then, given that the government spending are given, Equation (3.16) implies that the debt b_t adjust downward. This adjustment requires one or several tax rates to be adjusted. Which of the tax should be adjusted is *a priori* indeterminate. In this paper, I adopt a purely positive approach to the problem. Following Tinbergen's rule, only one instrument will be used to achieve this increase in tax revenues. In what follows, as a benchmark experiment, the labor tax will be used to adjust tax revenues, holding all other tax rates (and the lump sum tax) constant.[6] Adjustment in the consumption tax will also be considered in a separate experiment as a sensitivity analysis exercise.

The adjustment in the debt/output ratio remains to be described. Following Erceg and Lindé (2012), policymakers are assumed to reduce public debt gradually to avoid large adverse consequences for output. This is implemented by assuming that the targeted debt/output ratio, $b_t^\star$, follows the exogenous process

$$\log b_t^\star = \rho_b \log b_{t-1}^\star + (1-\rho_b)\left(\log\left(\frac{\overline{b}}{\overline{y}}\right) + \varepsilon_t^b\right) \tag{3.19}$$

[6]Note that things are a bit more subtle. In a general equilibrium, tax revenues will adjust for two reasons: *(i)* adjustment in the tax instrument (the margin) and *(ii)* adjustment in the taxed revenue (general equilibrium effect).

where $\overline{b}/\overline{y}$ denotes the initial steady state value of the debt/output ratio and $\{\varepsilon_t^b\}_{t=0}^{\infty}$ is an exogenous sequence that will control for the fiscal consolidation. This process is akin to a simple AR(1) process where the persistence is controlled by parameter ρ_b. For instance, should ε_t^b be a purely transient shock (*e.g.* $\{\varepsilon_t^b\}_{t=0}^{\infty} = \{\varepsilon^b, 0, \ldots\}$) with $\varepsilon^b < 0$, $b_t^\star$ would drop on impact and converge back to $\log(\overline{b}/\overline{y})$ monotonically. Fiscal consolidation in this setting will then be implemented by considering the sequence $\{\varepsilon_t^b\}_{t=0}^{\infty} = \{\varepsilon^b, \varepsilon^b, \ldots\}$, with $\varepsilon^b < 0$, implying that $b_t^\star$ will converge smoothly to $\log(\overline{b}/\overline{y}) + \varepsilon^b < \log(\overline{b}/\overline{y})$. The coefficient ρ_b controls the speed of debt target adjustment such that high values of ρ_b lead to slower adjustments.

3.2.6 General Equilibrium

A competitive general equilibrium is a sequence of prices $\mathscr{P}_t \equiv \{r_{t+i}, z_{t+i}\}_{i=0}^{\infty}$, a sequence of wages $\mathscr{W}_t \equiv \{w_{t+i}\}_{i=0}^{\infty}$, a sequence of taxes $\mathscr{T}_t \equiv \{\tau_{t+i}^w, \tau_{t+i}^c, \tau_{t+i}^k, T_{t+i}\}_{i=0}^{\infty}$, a sequence of policy instruments $\mathscr{G}_t \equiv \{g_{t+i}, f_{t+i}, b_{t+i}^\star\}_{i=0}^{\infty}$ and a sequence of quantities $\mathscr{Q}_t \equiv \{c_{t+i}, y_{t+i}, k_{t+i}, n_{t+i}, v_{t+i}, b_{t+i}\}_{i=0}^{\infty}$ such that

1. for a given sequence of prices, $\mathscr{P}_t$, a sequence of wages, $\mathscr{W}_t$, a sequence of taxes, $\mathscr{T}_t$ and a sequence of policy instruments, $\mathscr{G}_t$, the sequence of quantities, $\mathscr{Q}_t$, solves the optimization problems of the agents,

2. for a given sequence of prices, $\mathscr{P}_t$, a sequence of taxes, $\mathscr{T}_t$, a sequence of policy instruments, $\mathscr{G}_t$, and a sequence of quantities, $\mathscr{Q}_t$, the sequence of wages, $\mathscr{W}_t$, is set according to the wage bargaining process,

3. for a sequence of quantities, $\mathscr{Q}_t$, a sequence of wages, $\mathscr{W}_t$, a sequence of taxes, $\mathscr{T}_t$ and a sequence of policy instruments, $\mathscr{G}_t$, the sequence of prices, $\mathscr{P}_t$, clears the capital and good markets,

4. for a sequence of quantities, $\mathscr{Q}_t$, a sequence of wages, $\mathscr{W}_t$, a sequence of quantities, $\mathscr{Q}_t$ and a sequence of policy instruments, $\mathscr{G}_t$, the sequence of taxes, $\mathscr{T}_t$, implies that the government budget constraint is satisfied.

3.3 Model calibration

The model presented in the previous section does not admit an analytical solution and is therefore solved numerically, using Dynare. This requires the structural parameters to be assigned values. The model is calibrated for the post-WWII US economy at the quarterly frequency. Table 3.2 reports the parameter values.

The parameters pertaining to preferences and technology are standard and borrowed from the Real Business Cycle literature. The psychological discount factor, β, is set such that the rental rate of capital is about 4% ($\beta = 0.99$). The capital elasticity in the production function, α is set to match the capital share of income in the National Income and Product Accounts ($\alpha = 0.33$).[7]. The capital depreciation rate, δ is set such that the annual depreciation rate is equal 10 percent ($\delta = 0.025$). The investment adjustment cost parameter, φ, is set to be 2, which lies in the range of values considered in the DSGE literature.

[7]Note that since the wage rate in this model economy does not correspond to the marginal product of labor, $1 - \alpha$ is not equal to the labor share of total income. $(1 - \alpha)$ equals the sum of the labor share of total income and the return to investing in job search. Contrary to the standard neoclassical growth model in which labor's share of income is constant, the model with labor frictions in the labor market exhibits a labor share that varies over the business cycle, thereby mirroring this variable's behavior in the data.

Table 3.2: Model parametrization

Param.	Value	Interpretation	Target
β	0.990	discount rate	4% annual interest rate
α	0.330	capital elasticity of output	33% capital share of income
δ	0.025	Capital depreciation rate	10% annual depreciation rate
G/Y	0.201	st. st. government spending in output ratio	Average government spending to GDP ratio
τ^w	0.250	st. st. labor income tax rate	Estimate of average effective labor income tax rate by Mendoza, Razin, and Tesar (1994)
τ^c	0.060	st. st. consumption tax rate	Estimate of average effective consumption tax rate by Mendoza, Razin, and Tesar (1994)
τ^k	0.430	st. st. capital income tax rate	Estimate of average effective capital income tax rate by Mendoza, Razin, and Tesar (1994)
s_t	0.8094	probability of finding a job	
q_t	0.9469	probability of filling a vacancy	
ψ	0.0648	separation rate	
θ		labor market tightness	
v		vacancy	
a	0.07	vacancy posting cost	
η	0.05	worker's bargaining power	
X		outside option	
n	0.945	steady state employment	
ν	2	labor disutility parameter	–

Annual debt is assumed to amount to 100% of GDP, which, on a quarterly basis, implies a debt to output ratio of 4. This corresponds to the amount of debt required to finance government spending that constitutes 20% of GDP –the average government share over the post-WWII period in the US. The steady state level of taxes is borrowed from Mendoza, Razin, and Tesar (1994), who sets τ^w, τ^c and τ^k, equal to the average effective US tax rates for labor, consumption and capital income: 0.25, 0.06 and 0.43 respectively. The parameters pertaining to the rules (3.18) and (3.19) will be given when we describe the baseline experiment.

The parameters pertaining to the labor market are set following the approach outlined in Shimer and Rogerson (2010) and Hagedorn and Manovskii (2008b).[8] Their approach amounts to set the parameters of the labor market to match, as closely as possible, the volatility of market tightness in the data. This is achieved as long as the model is also able to replicate the data along the other dimensions, namely the volatility of vacancies, the volatility of unemployment, and the correlation between vacancies and unemployment. The data indicate that the probability of finding a job (s_t) within the quarter is 0.8094, and that to fill a vacancy, q_t, is 0.9469. They also give the separation rate to be $\psi = 0.0648$. Using the probability of finding a job, the separation rate and the law of motion of aggregate employment in the steady state, the steady-state level of employment is

$$n = \frac{s(\theta)}{\psi + s(\theta)} = 0.945$$

implying an unemployment rate of 5.5%.

Given a value for the steady state employment, the other labor market variables are solved using the remaining equations and the remaining parameters can be set. The elasticity in the disutility of labor, ν, is set to 2, which lies well within the range of values used in the literature.[9] Following Hagedorn and Manovskii (2008b) the total cost of posting a vacancy, in terms of average quarterly labor productivity, is set to 4.67 percent. Given that the labor's share of income averages 0.66 in US data, this implies a quarterly vacancy posting cost, a, of 0.07. Also, following Hagedorn and Manovskii (2008b), the worker's bargaining power, η is set at 0.05. Using the wage setting equation, and the combination of low vacancy posting costs, together with a bargaining power favoring firms, leads to a disutility parameter, ϑ of 0.349. Finally, the outside option is calibrated as

[8]Note that since Hagedorn and Manovskii (2008b) calibrated the model on a weekly basis, their approach is modified to accommodate the quarterly frequency.

[9]Although this parameter does not correspond to the inverse Frisch elasticity, it is reminiscent of it. Estimates for this elasticity range from 0.333 in representative macroeconomic studies to 100 for microeconomic studies.

$X_t =$ labor replacement rate $\times\, w_t(1-\tau_t^w)$.[10]

3.4 Results

This section discusses our baseline experiment and presents our main results.

3.4.1 Transition Analysis

In this paper, fiscal consolidation takes the form of a permanent 25% points decrease in the debt to output ratio ($\varepsilon^b = -0.25$). However, this reduction in the size of debt is achieved smoothly. More precisely, the persistence parameter of the debt target process (3.19), ρ_b, is set such that half of this adjustment is performed within a business cycle –*e.g.* 6 years[11] ($\rho_b = 0.875$).[12] In the fiscal rule the parameter governing the reaction of fiscal receipts to debt adjustments, γ_1 is set to 0.8, such that half of the adjustment is completed within a business cycle or, in other words, within 6 years. Given the importance of this parameter, variations in its value will be considered in Section 3.5. Given that the model does not consider stochastic shocks, the model is solved under perfect foresight using the relaxation method proposed by Boucekkine (1995), as implemented in Dynare. This approach allows to preserve all potential non-linearities affecting the adjustment dynamics. Finally, in the baseline experiment, only the labor tax rate is allowed to adjust and government spendings are kept constant over time.

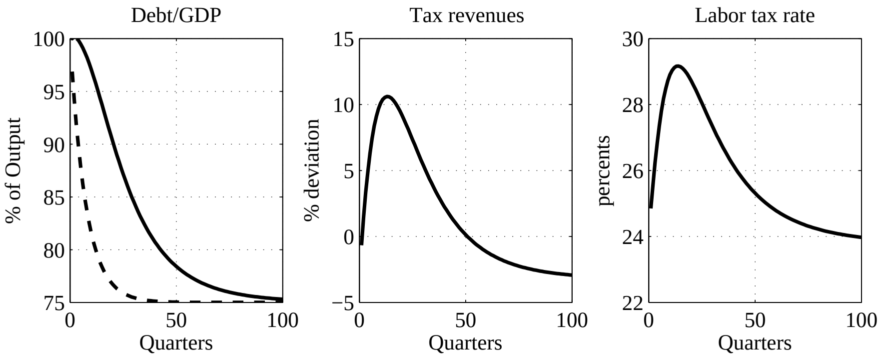
The left panel of Figure 3.1 reports *(i)* the evolution of the debt target ratio, $b_t^\star$, (dashed line) alongside *(ii)* the evolution of the actual debt to GDP ratio in the economy (plain line). For the sake of interpretation, the debt/output ratio is expressed in annualized terms. Initially, the actual debt/output ratio is on target, 100% of GDP. As of the next period, the target debt ratio starts adjusting toward

[10]The statistics on labor market replacement rate comes from Bureau of Labor Statistics and is set at 0.6.

[11]This value corresponds to the average duration of a complete business cycle from trough to trough (or from peak to peak) for the post–war US economy, as reported by the NBER.

[12]In Section 3.5, other levels and speed of debt reduction will also be considered as a way to provide a better understanding of the consolidation dynamics.

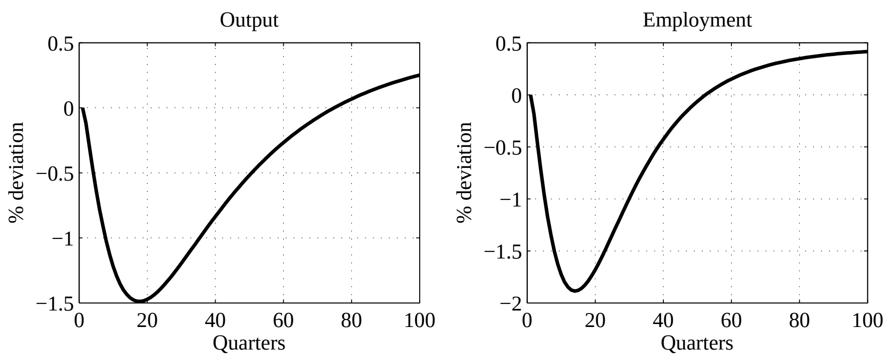
Figure 3.1: Fiscal Consolidation



its new long run level, 75%. Note the target debt ratio adjusts much quicker to its new long–run value than the actual debt ratio. For instance, half of the adjustment of the target has to be done within 6 quarters for the actual debt ratio to achieve half of its adjustment in 6 years. This can be interpreted as the willingness of the policymaker to anchor the expectations of the agents to the new target in a relatively short time. This lag in the actual debt adjustment implies that the gap in the dynamics of actual and target debt ratio is positive, immediately after the implementation of the policy, and remains positive throughout the transition. This implies that tax revenues have to increase in order to finance the constant flow of government expenditures (see middle panel of Figure 3.1). The government substitutes debt for tax revenues, therefore creating a negative wealth effect on the agents. As will become clear later, the presence of the negative wealth effect will lead to a decrease in consumption and investment –and therefore capital accumulation– which will affect negatively the tax base. Tax rates have to adjust. Given that both the consumption tax, the capital income tax and lump sum taxes are held constant, the labor tax has to increase to permit the increase in the tax revenues (see right panel of Figure 3.1). The tax increases from 25% to about 30% at the peak. As the debt reduction process approaches completion, the effort in debt reduction is compensated by a reduction in debt services. Tax revenues can then be lowered, which translates eventually into a reduction in the labor tax that eventually reaches a lower long-run level of 23.8%.

Figure 3.2 illustrates the effects of fiscal consolidation on output and employment, and reports the percentage deviations of both variables from their initial steady state level. Output and employment are left unaffected on impact as both employment and capital are predetermined in the model. As of the second period, both employment and output decrease. The government therefore creates a recession in order to achieve its debt reduction objective. At the trough of the recession (4.5 years following the beginning of the adjustment), output is 1.5% below its initial steady state. Employment reaches its trough of 1.9 percentage points in deviations from its steady state after 3.35 years. The negative effects on employment and output are persistent. Employment reaches back its steady state after 12.9 years,

Figure 3.2: Evolution of Output and Employment following 25% debt reduction

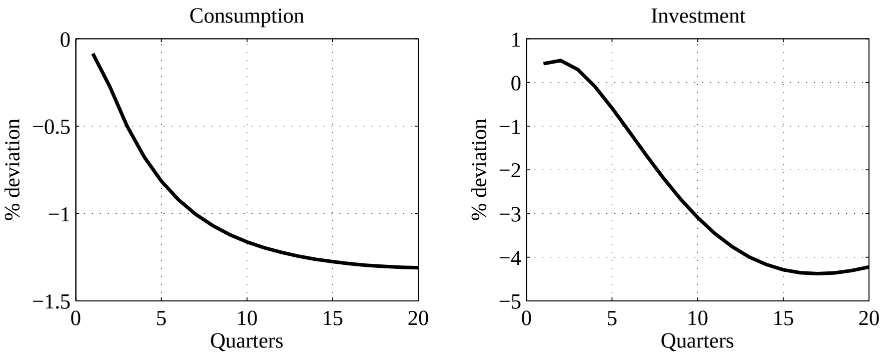


and only after this date the economy starts to benefit from its fiscal consolidation effort, and both its employment level and output increase above the initial steady state. There clearly is an intertemporal tradeoff the policymaker has to consider. Reduction of debt requires to plunge the economy in a recession for a long period, before output increases and unemployment recedes in the longer run.

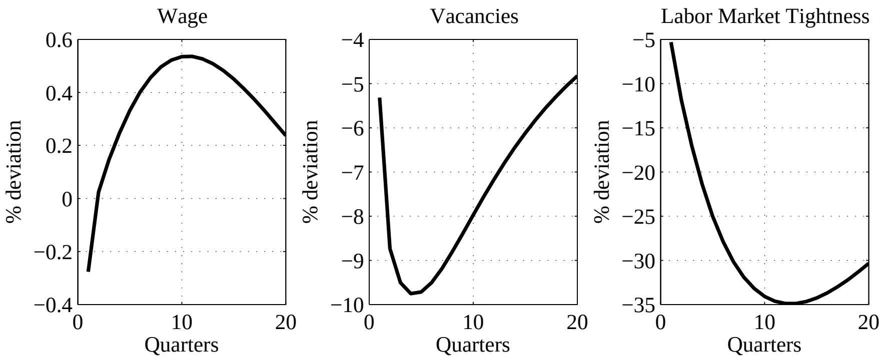
As aforementioned, the fiscal consolidation process entails an increase in the labor tax rate. The associated increase in the tax burden creates a negative wealth effect that, everything else equal, reduces both consumption and investment (see Figure 3.3). This is the standard effect, also present in the standard neoclassical

Figure 3.3: Macroeconomic responses (Benchmark Experiment)

(a) Good Market



(b) Labor Market



model, that reduces the demand for goods and triggers a recession. The increase in the labor tax has another effect on the economy that is fundamentally related to the presence of labor frictions. From the wage setting equation (3.15), we have

$$\frac{\partial w_t}{\partial \tau_t^w} = \frac{(1-\eta)(w_t - X_t)}{1-\tau_t^w(1-\eta)} > 0 \Longleftrightarrow w_t > X_t$$

Given that the outside option corresponds to a fraction of the wage in the model, an increase in the labor tax leads to an increase in the wage. This reflects the fact that the household uses the Nash bargaining process to be compensated for the increase in the tax burden. The increase in the wage reduces the marginal value of employment for the firms, which then cut on their vacancy postings (see middle of Panel (b) in Figure 3.3). Given that unemployment is predetermined, the labor market conditions improve (θ_t decreases, see left of Panel (b) in Figure 3.3). On the one hand this improves the situation of firms that then face a larger probability of filling a vacancy, q_t (positive trade externality). On the other hand, the situation of the household deteriorates as she now faces a lower probability of finding a job, s_t (congestion effect). This therefore increases unemployment, and its duration. Hence the persistent drop in employment in the economy.

As already outlined in Section 3.3, the above described transitional dynamics are obtained starting from a 5.5% unemployment rate. If, instead, higher unemployment rates are considered —as observed in southern European countries— the results are, if at all, barely affected. In other words, these results are not affected by the initial steady state level of unemployment, and our analysis remains valid whether the economy is initially started from a high or low unemployment rate.

3.4.2 Cumulative losses

This section offers a quantitative representation of the adjustment dynamics described in the previous section. More precisely, cumulative losses of output and employment are computed. The cumulative loss, $\ell(y,k)$, of output (respectively employment, $\ell(n,k)$) at horizon k is given by

$$\ell(y,k) = -100 \times \sum_{j=0}^{k} \left(\frac{y_{t+j} - \overline{y}}{\overline{y}} \right)$$

such that $\ell(y,k)$ is a positive number –expressed in percentages– that corresponds to the cumulative losses the economy experience, in terms of output (resp. employment), between period t and period $t+k$. In the case of output, the discounted loss, $\ell(y;\beta)$ is also computed

$$\ell(y;\beta) = -100 \times \sum_{j=0}^{\infty} \beta^j \left(\frac{y_{t+j} - \overline{y}}{\overline{y}} \right)$$

where $\beta \in (0,1)$ is the psychological discount factor of the household.

Table 3.3 report the cumulative output and employment losses associated to the fiscal consolidation process at various horizons. Inspection of Table 3.3 reveals that

Table 3.3: Cumulative Losses

Horizon	1 Quarter	1 Year	2 Years	5 Years	20 Years	50 Years	Discounted
Output	0.12	0.88	4.23	20.93	56.14	12.98	17.37
Employment	0.18	1.35	6.33	27.86	43.70	-8.88	–

fiscal consolidation episodes are costly in the short to medium run, both in terms of output and in terms of employment. For instance, after one year, the economy would have experienced about 1% output loss and would have, in total, lost 1.3 percentage points employment. Given the persistence of the recession, these losses amplify over time, and after 5 years, the cumulative loss in terms of output is about 21%, 30% for employment. Losses recedes as the horizon increases since the beneficial effects of fiscal consolidation kick in. It takes 58 years for the cumulative output losses to cancel out and eventually turn into gains, 45 years for employment. This, once again, points to the existence of an intertemporal trade-off between the long–run gains of debt reduction on the one hand, and the short–run employment and output losses generated by fiscal consolidation. In the case of output, the discounted loss is still sizable, 17%, over the whole adjustment (from period t to ∞), meaning that, given the discount factor of the household, the short–run losses outweigh the long run gains.

3.5 Sensitivity analysis

The preceding results have shown that the output and employment costs of reducing public debt can be sizable in the short to medium run, and that agents have to be patient enough to experience the gains associated to such policies. This section assesses the robustness of the previous findings to alternative settings for the consolidation policy. In particular, the sensitivity to the state of the business cycle, the speed and size of the debt reduction, the presence of alternative instruments (government spendings, and other taxes) and the timing of the consolidation are investigated.

3.5.1 Recessions

The recent fiscal consolidation episode has taken place within a particular economic environment: most economies were experiencing a recession. This section investigates the role of the state of the business cycle for the impact of debt reducing policies on employment and output. To this end, we compare the response of output and employment to the fiscal consolidation policy described in the previous section when the economy is started from steady state to the case where the economy is plunged into a recession initially. The recession is triggered by a downward shift in total factor productivity A_t that brings output 2.5% below trend on impact. Figure 3.4 reports the dynamics of output and employment during the fiscal consolidation episode. The plain dark line corresponds to the benchmark experiment described in the previous section, whereas the red line corresponds to the deviation of output from its path in recession during the fiscal consolidation. The results indicate that reducing debt in a recession does not generate significantly larger output and employment losses than when the economy is started from its steady state. The cumulative losses are marginally larger than in the benchmark experiment in the short-run, as witnessed by Table 3.4. As time goes on, the losses increase a bit more during a recession. For instance, fiscal consolidation yields a 30% cumulative employment loss when the fiscal consolidation is started in a recession, 28% when started from steady state. The reason is that in a recession fiscal policy

Figure 3.4: Output and employment responses during recession

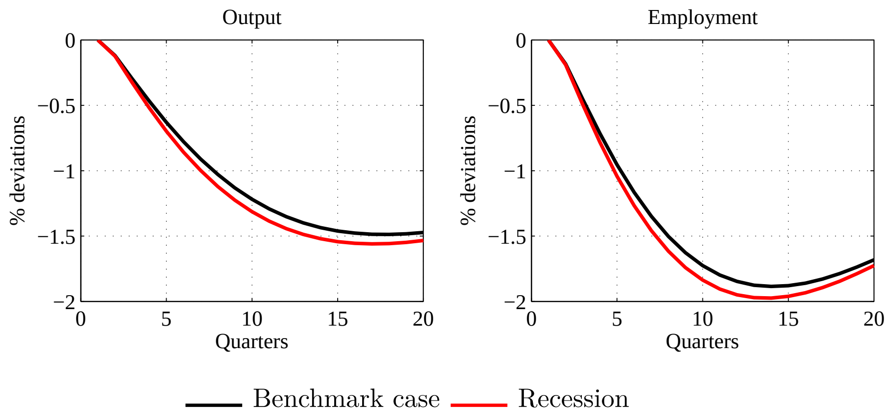


Table 3.4: Cumulative losses due to fiscal consolidation

Horizon	1 Quarter	1 Year	2 Years	5 Years	20 Years	50 Years	Discounted
Output	0.12	0.97	4.65	22.32	58.08	14.47	18.93
Employment	0.19	1.47	6.86	29.38	44.74	-8.20	–

is constrained as there is a direct trade-off between the fiscal consolidation and output stabilization in the recession. Thus, there are two opposing demands on the labor tax adjustment; the fiscal consolidation demanding a hike in wage tax while the output stabilization calling for a fall in wage tax. Consequently, the fiscal consolidation will be slower in recession compared to the benchmark scenario, reflecting a direct trade-off between the fiscal consolidation and output stabilization.

3.5.2 Consumption taxes

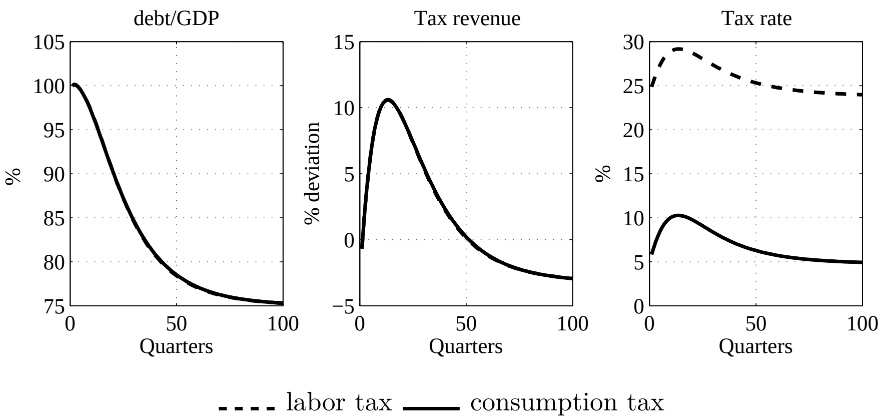
In the benchmark experiment, the debt reduction was achieved by adjusting the labor tax rate holding the other taxes —namely consumption and capital taxes— constant, at their steady state levels. In this section, I investigate the effects of fiscal austerity as achieved through adjustment of the consumption tax rate (for example, retail sales tax, a value-added tax, and a consumption-type flat tax) instead.[13]

Figure 3.5 reports the adjustment dynamics of fiscal aggregates and the tax rate during the fiscal consolidation. The consumption tax increases from 6% —its steady state level in the initial regime— to about 10.3% at the peak (reached in 3.5 years following the beginning of fiscal austerity) — a 4.3 percentage points increase which is of the same order as the increase in the labor tax. As the debt reduction process approaches completion, the effort in debt reduction is compensated by a reduction in debt services. Tax revenues can then be lowered, which translates eventually into a reduction in the consumption tax that eventually reaches a lower level of 4.75%.

The initial increase in the consumption tax makes consumption relatively more expensive. As a way to smooth their consumption over time, the households extract a greater surplus during the wage bargaining process which puts upward pressure on the real wage (see equation (3.15) which is an increasing function of the consumption tax). The real wage increases, but the marginal value of a new employee for the firm decreases which leads to a fall in vacancies. However, this

[13] Such a consumption tax adjustment was recently put forward in France as a way to obtain a social V.A.T. (see Fève, Matheron, and Sahuc (2010)).

Figure 3.5: Fiscal Consolidation: Consumption Tax (I)

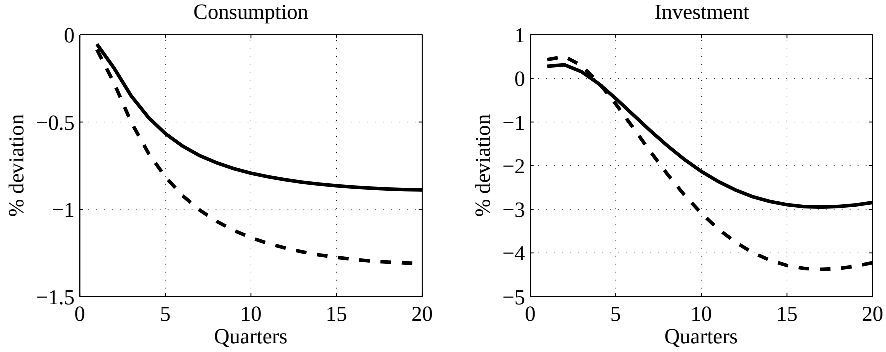


effect on the real wage is indirect and as such results in a smaller decrease in the wage and vacancy posting compared to the case of the labor tax adjustment. Hence, the permanent income of the agents is not as affected and consumption decreases less than in the benchmark case, even though the adjusting tax is the consumption tax. Likewise the adjustment of investment is dampened. Employment reaches back its steady state after 12.9 years, and only after this date the economy starts to benefit from its fiscal consolidation effort, and see both its employment level and output be above the initial steady state. Just as in our benchmark case, the policy maker faces an intertemporal tradeoff: plunging the economy in a recession for a long period, before output increases and unemployment recedes in the longer run.

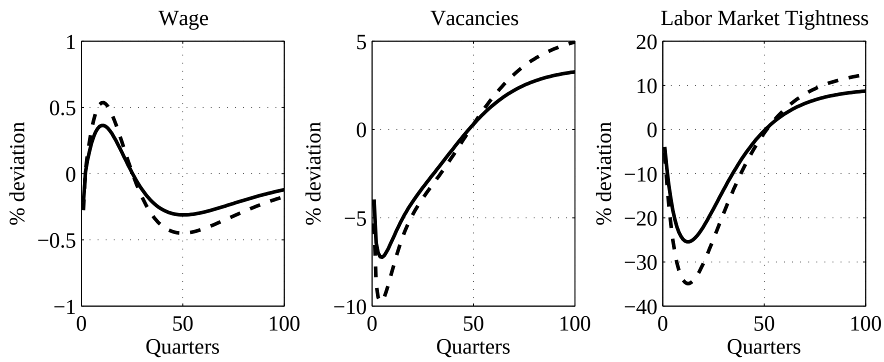
Inspection of Figure 3.7 reveals, that compared to using the labor tax rate, the use of consumption tax generates *(i)* lower output loss –it stands at a 1.01% deviations from its initial steady state compared to 1.5% for the labor tax (reached in 4.5 years following the beginning of fiscal austerity), *(ii)* lower employment loss of 1.28% after 3.5 years – for the labor tax rate this is a 1.9% deviations from its steady state after 3.35 years. The negative effects on employment and output are persistent.

Figure 3.6: Macroeconomic responses (Consumption Tax Experiment)

(a) Good Market

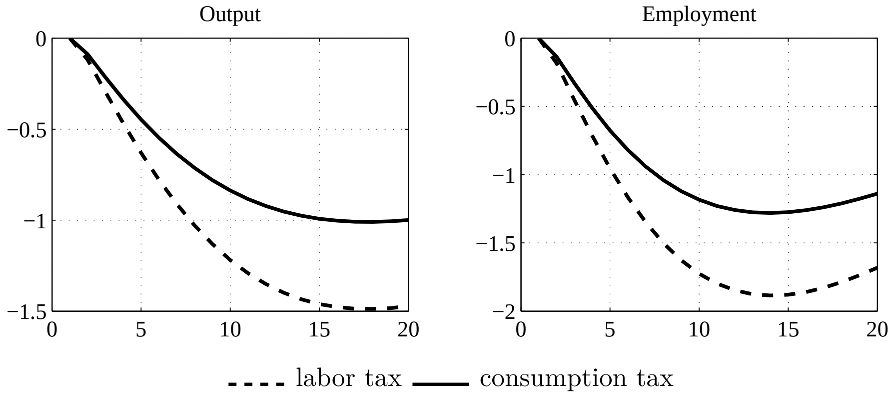


(b) Labor Market



- - - - labor tax —— consumption tax

Figure 3.7: Evolution of Output and Employment (II)



This is confirmed by inspection of Table 3.5 which reveals that, when government adjusts the consumption tax rate, fiscal consolidation episodes are less costly in the short to medium run, both in terms of output and in terms of employment. For instance, after two years, the economy would have experienced an output loss of about 3% and would have, in total, lost 4.5 percentage points of employment– when using the labor tax the output loss is around 4% and the employment loss is about 6%. Given the persistence of the recession, these losses amplify over time. In the long run, after 50 years, the economy experiences cumulative gain of 9.2% for employment – in the case of a labor tax this is lower and stands at 8.9%. Losses recede as the horizon increases since the beneficial effects of the fiscal consolidation kick in. Under the consumption tax adjustments, it takes one year less for the cumulative output losses to cancel out and eventually turn into gains, 57 years versus 58 years under the labor tax adjustments. In the case of output, the discounted loss is still sizable, 10.2%, over the whole adjustment (from period t to ∞), but much lower than for the labor tax, 17%. On the other hand, for both tax regimes, it takes the same length of time for the cumulative employment losses to cancel out – that is 45 years.

Table 3.5: Cumulative losses: Consumption Tax Adjustment

Horizon	1 Quarter	1 Year	2 Years	5 Years	20 Years	50 Years	Discounted
Output	0.09	0.64	2.98	14.36	37.97	6.08	10.17
Employment	0.14	0.98	4.45	19.11	29.25	-9.15	–

For the consumption tax adjustment, the intertemporal trade-off between the long–run gains of debt reduction on the one hand, and on the other hand the short–run employment and output losses generated by fiscal consolidation, is still present. However these tend to be smaller compared to the labor tax adjustment. These results indicate that, in terms of employment and output losses, the consumption tax is better suited for fiscal austerity.

3.5.3 Speed versus Amplitude

The fiscal consolidation is characterized by *(i)* the persistence and *(ii)* the amplitude of the debt adjustment. In particular, as already explained above, the higher the persistence, the smaller the amplitude effect, and vice versa. Intuitively, by becoming more "aggressive" and by speeding up the reduction of public debt has the advantage of reducing the time period during which the economy experiences output and employment losses. However, a larger effort may be required in the beginning of the fiscal consolidation given that the same adjustment has to be performed in a shorter time. For the policy making purposes, the government can strike the right balance between these two effects by varying *(i)* the speed of debt adjustment, ρ_b, and *(ii)* its own "aggressiveness" towards the debt adjustment, γ_1. As a way to investigate this issue, Panels (a) of Figure 3.8–3.9 report the transition dynamics of fiscal instruments, output and employment as the speed of the debt adjustment is varied, with a half–life ranging from 4 to 27 years. This adjustment is controlled by changing ρ_b in the range 0.6 to 0.99 –the benchmark case setting being $\rho_b = 0.875$. Panels (b) of Figure 3.8–3.9 illustrate the transitional paths when the initial amplitude of the debt adjustment is varied. This is achieved by controlling the degree of "aggressiveness" of the fiscal authority to debt reduction,

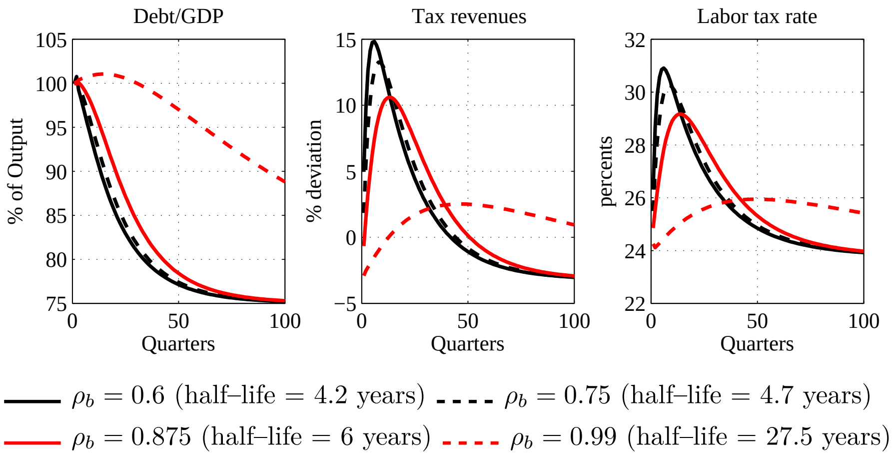
γ_1, which is varied from 0.2 to 0.99 – with the benchmark case set at 0.8.

The main implications of varying the speed of the adjustment can be gathered from Figure 3.8. A faster fiscal consolidation (lower ρ_b) requires that larger tax revenues be raised upfront (see middle panel of Panel (a) of Figure 3.8), and leads to a larger and shorter increase in the labor tax rate (see right panel of Figure 3.8). For instance, the peak in the evolution of the labor tax rate in the benchmark experiment occurs 3.5 years after the beginning of the consolidation and amounts to a tax rate of 29.2% (25% in the initial steady state). When the half life of the debt ratio adjustment is shortened to 4.2 years ($\rho_b = 0.6$), this peak is reached after 1.5 year with a labor tax of 31%. Very similar results are obtained when, instead, the government increases the magnitude of the initial debt reduction. This is achieved by increasing its own aggressiveness towards debt reduction, γ_1. In the benchmark experiment, $\gamma_1 = 0.8$, the labor tax rate amounts to 29.14% of income at the peak of the tax rate adjustment, which occurs 3.75 years after the beginning of fiscal consolidation. When the government adopts a more aggressive approach to debt reduction, $\gamma_1 = 0.99$, this peak is reached in 3.25 years in the labor tax of 29.92%. In that context, the household needs to be given extra compensation in the wage bargaining process, and the wage increases more relative to the benchmark experiment. Firms post relatively less vacancies and the employment loss is larger (see right panel of Figure 3.9). Likewise, and for similar reasons, the output loss is also larger.

Most of the adjustment being accomplished over a shorter period of time, the increase in the tax rate is shorter–lived. Accordingly the employment loss is less persistent. These results are reflected in Table 3.6 which reports the cumulative output and employment losses associated with these experiments. The table clearly indicates that faster debt reduction is associated with larger employment losses in the short run (1.54 percentage point for the case $\rho_b = 0.6$ versus 0.18 percentage point in the benchmark), but these employment losses tend to recede quicker. For instance, the cumulative employment loss canceled out after 45 years in the benchmark experiment, 43 years in the fast adjustment case. Interestingly, while the tax adjustment is much quicker in the $\rho_b = 0.6$ case compared to the benchmark,

Figure 3.8: Varying the Speed and "Aggressiveness" of Debt Adjustment (I)

(a) Varying the Speed of Debt Adjustment



(b) Varying the Fiscal Authority "Aggressiveness"

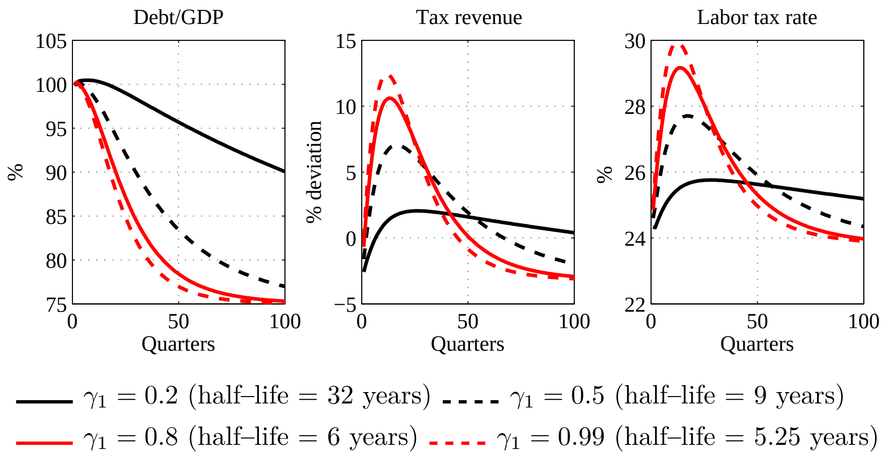
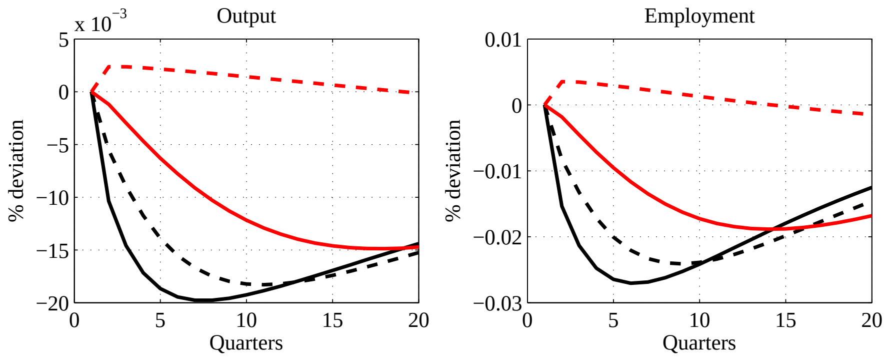


Figure 3.9: Varying the Speed and "Aggressiveness" of Debt Adjustment (II)

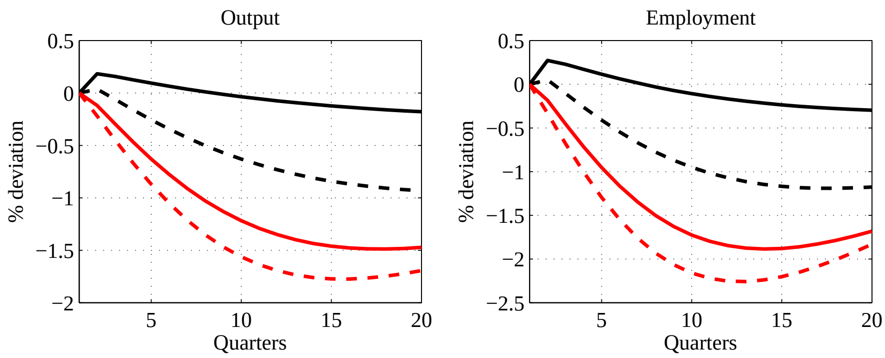
(a) Varying the Speed of Debt Adjustment



$\rho_b = 0.6$ (half–life = 4.2 years) $\rho_b = 0.75$ (half–life = 4.7 years)

$\rho_b = 0.875$ (half–life = 6 years) $\rho_b = 0.99$ (half–life = 27.5 years)

(b) Varying the Fiscal Authority "Aggressiveness"



$\gamma_1 = 0.2$ (half–life = 32 years) $\gamma_1 = 0.5$ (half–life = 9 years)

$\gamma_1 = 0.8$ (half–life = 6 years) $\gamma_1 = 0.99$ (half–life = 5.25 years) this decrease in persistence does not translate to employment, nor to output. The reason for this is found in the matching process which generates a lot of persistence in the model.

As the speed of debt adjustment is reduced –say $\rho_b = 0.99$– the reverse mechanisms are at play. However, interestingly, a slower fiscal consolidation is accompanied by an increase in debt in the short run. This is due to the fact that the government can spread the debt adjustment over a longer period, and in that way can achieve some form of tax smoothing. The tax increases by much less in the transition (0.26 at the peak), and can even be lowered in the short run. This initial fall in the tax rate puts downward pressure on the wage, which in turn leads the firms to post more vacancies and hire more employees. Hence, in the short run, employment losses turn into employment gains, and fiscal consolidation actually generates mild employment and output gains. These gains are however short lasting and turn into employment losses after 7 years and persist longer 56 additional years.

Table 3.6: Cumulative losses: Varying Speed

Horizon	1 Quarter	1 Year	2 Years	5 Years	20 Years	50 Years	Discounted
Output							
$\rho_b = 0.600$	1.04	4.21	11.98	32.53	58.18	12.53	20.45
$\rho_b = 0.750$	0.55	2.62	8.98	29.65	58.53	13.52	20.30
$\rho_b = 0.875$	0.12	0.88	4.23	20.93	56.14	12.98	17.37
$\rho_b = 0.990$	-0.24	-0.70	-1.47	-2.33	13.07	18.93	1.30
Employment							
$\rho_b = 0.500$	1.54	6.15	16.81	39.27	40.66	-12.68	–
$\rho_b = 0.750$	0.82	3.87	12.81	36.82	42.08	-11.09	–
$\rho_b = 0.875$	0.18	1.35	6.33	27.86	43.70	-8.88	–
$\rho_b = 0.990$	-0.35	-1.02	-1.98	-1.95	18.36	15.13	–

Similar results hold if the government instead decides to increase its aggressiveness to fiscal consolidation, γ_1. As it is evident from the results presented in Table 3.7, the more aggressive the government is about its fiscal consolidation plan, the larger are the losses in the short-run (for $\gamma_1 = 0.2$ we have employment gains of 0.27% while for the benchmark case, $\gamma_1 = 0.8$, there are employment losses of 0.18%). But these employment losses tend to disappear more quickly. With a lower extent of aggressiveness on the part of the government, $\gamma_1 = 0.2$, it takes 36.5 years for the cumulative employment losses to be canceled out compared to the benchmark experiment where it takes only 17.25 years.

Table 3.7: Cumulative losses: Varying Fiscal "Aggressiveness"

Horizon	1 Quarter	1 Year	2 Years	5 Years	20 Years	50 Years	Discounted
Output							
$\gamma_1 = 0.2$	-0.18	-0.47	-0.67	0.63	14.40	15.64	2.56
$\gamma_1 = 0.5$	-0.04	0.19	1.72	11.28	45.57	13.18	11.44
$\gamma_1 = 0.8$	0.12	0.88	4.23	20.93	56.14	12.98	17.37
$\gamma_1 = 0.99$	0.22	1.34	5.83	26.17	59.36	13.83	20.06
Employment							
$\gamma_1 = 0.2$	-0.27	-0.67	-0.83	1.69	16.46	11.34	–
$\gamma_1 = 0.5$	-0.05	0.32	2.73	15.99	40.61	-3.58	–
$\gamma_1 = 0.8$	0.18	1.35	6.33	27.86	43.70	-8.88	–
$\gamma_1 = 0.99$	0.33	2.02	8.56	33.95	43.63	-10.21	–

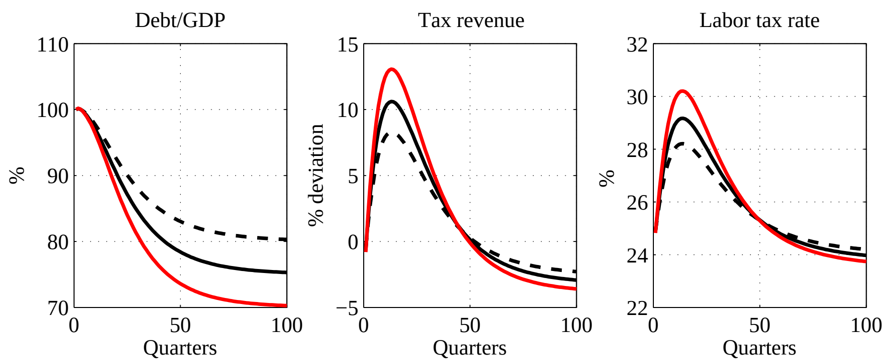
These transitional paths suggests that steady but gradual consolidation may be the strategy that has the lowest cost in terms of lost output and employment. Cutting too much debt today could throw the economy into a deep recession. Cutting it slowly creates a much milder recession, but a more persistent one. This is reminiscent of the gradualist versus "cold turkey" approaches described by Sargent (1983). On the one hand, a gradualist approach yields smaller losses with longer persistence. On the other hand, a "cold turkey" approach is associated with larger losses in the short–run but with shorter duration. Thus, the policymakers face a choice between two different approaches when deciding the policy which is best suited for its fiscal consolidation plan, each with its own tradeoffs.

3.5.4 The size of debt adjustment

The intertemporal tradeoffs that describe the fiscal consolidation –short–run employment (output) losses versus long–run gains– would be also present when the size of debt adjustment is varied.

Obviously, the larger reduction in the public debt requires a greater effort by the fiscal authority and is more costly in terms of employment (output) losses, but likewise, the long–run gains are also larger. However, one question remains open: are output and employment losses proportional to the size of the fiscal adjustment? Figures 3.10–3.11 explore the (dis)proportional effect of fiscal consolidation by reporting the transitional paths of fiscal instruments, employment and output as the size of debt adjustment, $b_t^\star$, is varied in the range of 20% to 30% – the benchmark case involves 25% debt adjustment. As expected, larger fiscal consolidations require larger adjustment in the tax revenues and the labor tax rate. For instance moving from a 20 to a 30% fiscal consolidation implies that the tax rate varies from 28 to 30% at the peak of its adjustment dynamics. Interestingly, the peaks reached in each experiment are concomitant. However, given that the size of the tax rate adjustment vary with the size of the debt reduction, the dynamics of debt are different. For instance, a 20% reduction has a half life of 8 years, whereas a 30% consolidation has a half life of 5 years. In other words, the dynamics are sensitive to the size of the debt reduction. To investigate the (dis)proportional effects of the

Figure 3.10: Varying the Size of Debt Adjustment (I)

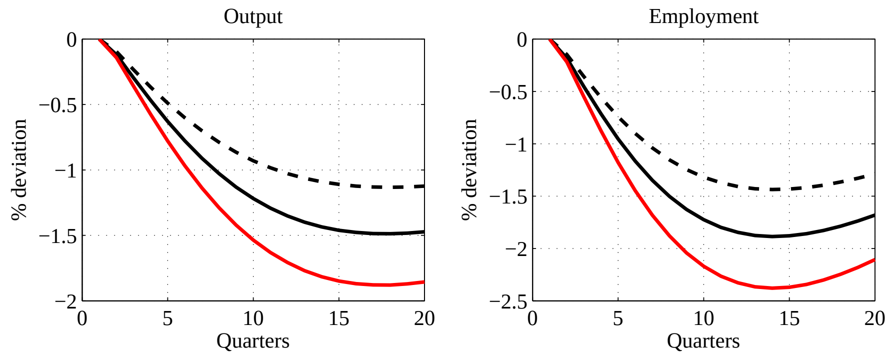


20% debt reduction, 25% debt reduction, 30% debt reduction.

size of the debt adjustment we plot in Panel (a) of Figure 3.11 the employment and output losses corresponding to 20, 25 and 30% fiscal consolidations. A government

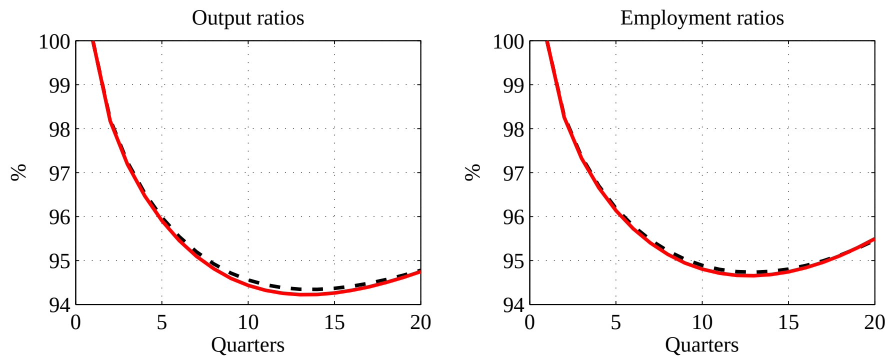
Figure 3.11: Varying the Size of Debt Adjustment (II)

(a) Output and Employment



- - - - 20% debt reduction, —— 25% debt reduction, —— 30% debt reduction.

(b) Output and Employment Ratios



- - - - 20%/25% adjustment ratio, —— 25%/30% adjustment ratio

willing to implement 20% debt reduction experiences employment and output losses of 1.44% and 1.1%, respectively, at the time of the peak response, in 3.5 years. A government willing to implement our benchmark debt reduction of 25% would then have to bear an additional employment loss of 0.45% (and an additional output loss of 0.34%). But yet an extra 5% increase in desired debt reduction would amount to an additional 0.49% in employment losses (and an additional 0.38% for output losses). So as expected from previous results, the size of employment (output) losses is positively related to the amplitude of the fiscal consolidation. Panel (b) of the figure reports the ratio of employment (output) losses corresponding to 20% and 25% debt reduction, and 25% and 30% debt reduction. This figure clearly shows that employment losses increase proportionally with the level of the debt reduction. Fiscal consolidation does not involve strong nonlinear effects.[14]

These results are also reflected in Table 3.8 which reports the cumulative output and employment losses associated with these experiments. The table clearly points to the existence of larger employment and output losses as we increase the desired debt reduction from 20% to 25% and then to 30%. In the short-run increasing debt reduction from 20% to 25% translates into 0.03% larger employment losses, but increasing a desired debt reduction for another 5% amounts to an additional 0.04% employment losses –the net difference of 0.01%. These tiny differences are explained by the way tax rate affects the wage in a nonlinear fashion.

Table 3.8: Cumulative losses: Varying Size

Horizon	1 Quarter	1 Year	2 Years	5 Years	20 Years	50 Years	Discounted
Output							
20%	0.10	0.70	3.28	15.99	43.92	9.72	13.02
25%	0.12	0.88	4.23	20.93	56.14	12.98	17.37
30%	0.14	1.08	5.25	26.34	68.86	16.71	22.25
Employment							
20%	0.15	1.07	4.91	21.35	34.60	-7.36	–
25%	0.18	1.35	6.33	27.86	43.70	-8.88	–
30%	0.22	1.65	7.84	34.94	52.95	-10.15	–

[14] A bit of qualification is in order. Employment and output losses are linearly related with the size of the fiscal consolidation. In that sense the process does not display any nonlinearities. However, while the dynamics of employment and output losses are proportional, those of debt are not. The differential adjustment of debt (and hence some form of nonlinearities) actually ensures the linearity in losses.

3.5.5 Endogenous government spending rule

So far, government spendings have been held constant over time, $g_t = \overline{g}\ \forall\, t = 0, \ldots, \infty$.[15] As our previous results indicated, a fiscal consolidation plunges the economy into a recession. The government may then use government spending as an "automatic stabilizer" (Blanchard (1984)) to dampen the adverse effects of debt reduction. A new tradeoff then emerges: fiscal consolidation versus output stabilization. The government may use government spendings to fight the recession, but by doing so it hinders the fiscal consolidation process. To investigate this tradeoff, this section considers the case in which government expenditures follow a simple rule

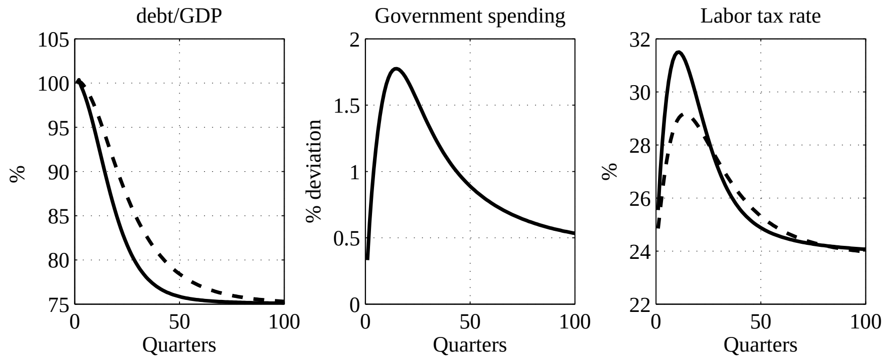
$$\log(g_t) = \rho_g \log(g_{t-1}) + (1 - \rho_g) \log(\bar{g}) + r_g \log\left(\frac{y}{\bar{y}}\right) \tag{3.20}$$

where $\rho_g \in (0, 1)$ and $r_g < 0$. The form of this rule stipulates that, in an attempt to influence the dynamics of output, the government raises public expenditures whenever output falls below its steady state level. Hereafter, I set $\rho_g = 0.5$ and $r_g = -0.5$.

Figures 3.8–3.13 compare the transitional paths of fiscal instruments, output and employment with exogenous government spendings (dashed line) —the benchmark experiment described in the previous sections— and those obtained when the government uses an active policy rule (plain line). As explained previously, the fiscal consolidation process triggers a recession. A government that has a concern for output stabilization then sees output falling below its steady state level and, according to rule (3.20), expands its expenditures. The financing of this policy cannot be achieved by issuing government bonds —this would obviously go against the fiscal consolidation— and calls for an increase in taxes. For instance, at the peak of its adjustment path, the labor tax rate reaches 31.5% compared to the 29% with constant government spending. This has two main consequences. First, the larger tax income collection accelerates the debt reduction process. Second, and more importantly, higher taxes magnify employment (output) losses. For instance, under constant government spendings, the maximal employment (resp. output)

[15] The government spending is set at its steady state value of $\overline{g} = 0.2\overline{y}$.

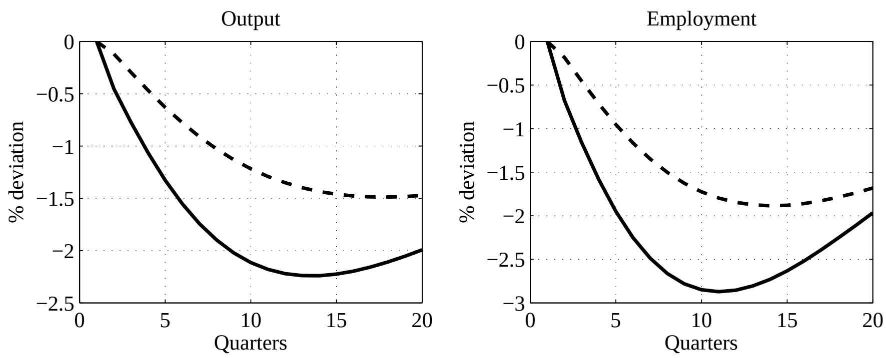
Figure 3.12: Varying Government Spending Rule (I)



- - - - Exogenous government spending rule (benchmark), —— Endogenous government spending rule.

loss was 1.8 percentage points (resp. 1.3%), under the active policy the maximal employment (resp. output) loss is 2.9 percentage points (resp. 2.2%)— a 60% increase. In other words, by pursuing the active policy, the government actually exaggerates the recession. Note however, that again the persistence/magnitude tradeoff occurs, i.e. while the recession is deeper it is shorter lasting, as the debt reduction is faster.

Figure 3.13: Varying Government Spending Rule (II)



- - - - Exogenous government spending rule (benchmark), —— Endogenous government spending rule.

These findings are also confirmed by results in Table 3.9 which reports the cumulative output and employment losses for this experiment. It is apparent that in the short-run employment (and output) losses are more than twice as large than when the government spending follows an exogenous process. For example, the employment losses are 0.68% compared to 0.18% in the baseline experiment (the output losses are 0.45% relative to 0.12% in the baseline case).

Table 3.9: Cumulative losses: Endogenous Government Responses

Horizon	1 Quarter	1 Year	2 Years	5 Years	20 Years	50 Years	Discounted
Output	0.45	2.29	8.81	34.57	69.43	26.51	30.70
Employment	0.68	3.42	12.78	43.55	46.85	-5.22	–

The results imply that the government pushes the economy into a deeper recession as it tries to pursue two conflicting goals: *(i)* debt reduction and *(ii)* output stabilization. Thus, the government needs to consider carefully the tradeoff between the two goals and its use of "automatic stabilizers".

3.5.6 Announced Fiscal Consolidations

The preceding sections considered scenarios where the government started the fiscal consolidation plan as soon as it announces it. This section investigates the case where the government announces in period t that it will implement a debt reduction policy starting in $t+4$.[16] In such a situation, agent's expectations play a key role and may affect the adjustment path.

From a technical point of view, announcement amounts to introduce a shock that is revealed to the agents 4 periods in advance in the debt target law of motion as

$$b_t^\star = \rho_b b_{t-1}^\star + (1-\rho_b)\left(\log\left(\frac{\overline{b}}{\overline{y}}\right) + \varepsilon_{t-4}^b\right) \tag{3.21}$$

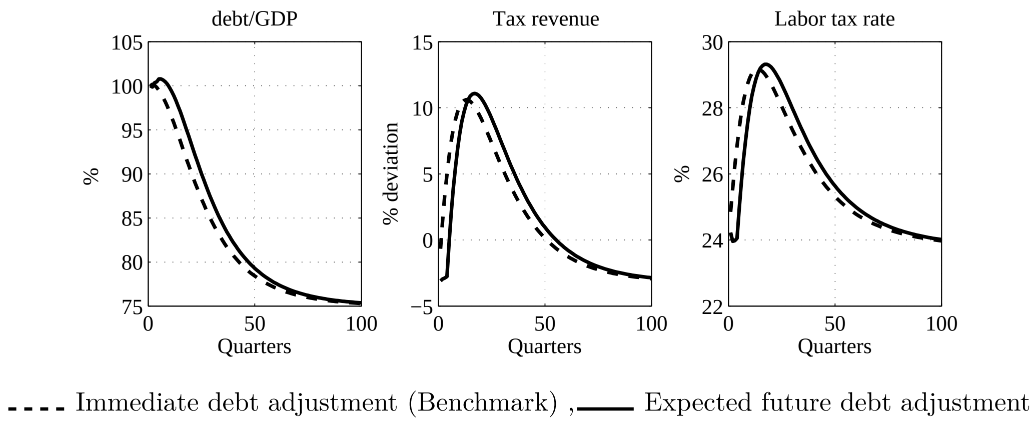
where, as previously, $\overline{b}/\overline{y}$ denotes the initial steady state value of the debt/output ratio and $\{\varepsilon_t^b\}_{t=-4}^{\infty}$ is an exogenous sequence that will control for the fiscal consolidation. ρ_b controls for the speed of fiscal consolidation adjustment.

[16]Note that full commitment and time consistency of the announcement will be assumed throughout. Departure from these assumptions is left for future research.

At the time the government makes the announcement, and for the next 4 periods, the target debt ratio remains unchanged —100% of GDP– and only starts adjusting in $t+4$. The adjustment dynamics that follow can then be better understood by splitting the adjustment into two sub–periods. The first one starts at the time of the announcement and ends with the implementation of the fiscal consolidation, and captures the mere effect of the announcement. During this period only announcement effects are at play. The second one starts with the effective implementation of the fiscal consolidation.

During the first sub–period, agents, who have perfect foresight, correctly expect that, as of period $t+4$, the target debt ratio will start converging to its new long-run level, 75%. Agents then expect higher future tax rates (see middle and right panels of Figure 3.14) and therefore that they will suffer a negative wealth effect in the future. The consumption smoothing behavior of the household makes her *(i)* cut on her consumption at the time of the announcement, and *(ii)* start accumulating more wealth, as a way to cushion themselves from higher taxes. In the current model, the agent has two ways to accumulate wealth: capital and bonds. Investment increases in the short-run as a way to accumulate capital. But, more interestingly for the purpose of this paper, the household also purchases government bonds. As shown in the left panel of Figure 3.14 public debt actually increases during that period. This leads to actual debt building up, which relaxes the government budget constraint. This explains why, in the few periods that follow the announcement, tax revenues and the labor tax rate fall (see middle and right panels of Figure 3.14). In other words, the announcement of the plan allows the government to substitutes tax revenue for debt, therefore mitigating the negative wealth effect on the agents. As already explained, the fall in the labor tax rate leads to a decrease in the wage which increases the marginal value of employment for the firm, which then posts more vacancies. On the one hand, a firm's prospect of filling a vacancy falls as it faces more competition from other firms in the labor market and as the probability of filling a vacancy, q_t falls (congestion externality). On the other hand, households find it, at first, easier to find a job as the probability of finding a job, s_t increases (positive trade externality). This, therefore, initially

Figure 3.14: Expected Future Debt Adjustment (I)

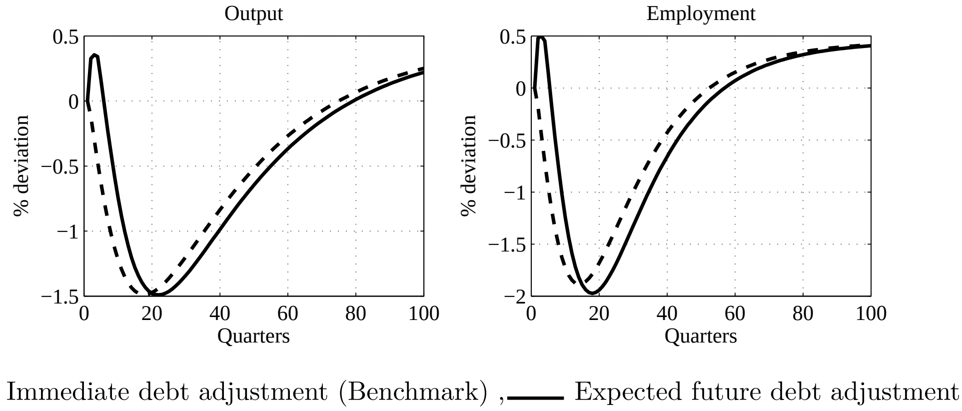


increases employment. The peak employment gain is reached in the third quarter and it amounts to 0.46%. In other words, the mere announcement of the fiscal consolidation ameliorates labor market conditions in the very short-run.

After 4 periods, the actual debt reduction begins and the adjustment dynamics enter in the second sub-period, during which the mechanisms at work are identical to those detailed in Section 3.4. The results indicate that the whole dynamics is essentially postponed by 4 quarters. For example, the peak in the evolution of the labor tax rate occurs 4 years after the fiscal consolidation commences, and 4 quarters later than in the baseline experiment, and amounts to 29.2% (exactly the same as in the baseline experiment). Employment reaches the trough after 4 years (once again 4 quarters later than in the baseline experiment) but the loss is slightly larger than in the baseline experiment and it amounts to 1.95% in deviations from the steady state (compared to just 1.9% in the baseline experiment). The output losses are also slightly higher than in the baseline case and amount to 1.49% (1.48% in baseline case).

Given the preceding discussion, it comes as no surprise that the government's announcement of its future fiscal consolidation plans is accompanied, in the short-run, by employment (and output) gains. For instance, there is an employment cumulative gain of 1.43% (and an output cumulative gain of 1.02%) recorded (see Table 3.10). These initial gains will be translated into lower overall cumulative

Figure 3.15: Expected Future Debt Adjustment (II)



losses than under the baseline scenario. For example, the discounted cumulative losses of output are equal to 15.6%, which amounts to a 1.8% decrease relative to the baseline case. This reduction is due to the prevailing negative wealth effect in the first sub-period that creates an economic boom which is then translated into the employment (and output) gains in the short-run and relatively lower losses in the future.

Table 3.10: Cumulative losses: Future Anticipated Debt Reduction

Horizon	1 Quarter	1 Year	2 Years	5 Years	20 Years	50 Years	Discounted
Output	-0.33	-1.02	-0.51	13.41	55.12	13.68	15.63
Employment	-0.48	-1.43	-0.18	20.31	45.97	-6.08	–

These transitional paths suggest that a pre-announced fiscal consolidation might generate lower costs in terms of employment (and output). This is obviously conditional on the maintained assumption that the government fully commits to implement the plan.

3.6 Monetary and Fiscal Policies

The preceding sections have investigated the adjustment dynamics to a fiscal consolidation episode in a real economy. The emphasis was put on the real aspects of such events, ignoring the potential nominal dimension of public debt reduction. However, the interplay between fiscal and monetary policy ought to have important consequences for the macroeconomy as monetary policy —by affecting the nominal interest— may hinder or ease fiscal consolidation. This section investigates this issue.

For monetary policy to matter, the model is amended in three ways. First, two types of firms are introduced in the economy. Final goods retailers sell a homogeneous good, which is an aggregate bundle of a set of intermediate goods that are produced by intermediate goods producers. Because each and every good is fully differentiated, the intermediate goods producers have monopoly power. They are therefore price setters. Second, these price setters face nominal rigidities in the form of price adjustment costs.[17] Finally, the central bank pursues an active monetary policy. Before going to the results, we describe how the model was changed by introducing the non neutral nominal dimension in the model.

3.6.1 Towards a Nominal Model

Final Goods-Producing Firms

There exists a representative final good producer that bundles a continuum of intermediate goods $y_t(j)$, $j \in (0,1)$, each purchased at price $P_t(j)$ on an imperfectly competitive market. This final retailer produces the homogenous good y_t that can be either consumed or invested using the technology

$$y_t = \left(\int_0^1 y_t(j)^{\frac{\varepsilon-1}{\varepsilon}} dj \right)^{\frac{\varepsilon}{\varepsilon-1}} \tag{3.22}$$

[17] Our results would be the same should a Calvo price setting mechanism be considered instead.

where $\varepsilon > 1$ is the elasticity of substitution between intermediate goods. The demand for each good j, as obtained by profit maximization, is then given by

$$y_t(j) = \left(\frac{P_t(j)}{P_t}\right)^{-\varepsilon} y_t \tag{3.23}$$

where P_t is the aggregate price level. Competition in the market for the final good drives the representative firm's profit to zero. The zero-profit condition, along with Equation (3.23), determines P_t as

$$P_t = \left(\int_0^1 P_t(j)^{1-\varepsilon} dj\right)^{1/(1-\varepsilon)} \tag{3.24}$$

Intermediate Good Producers

There is a continuum of intermediate goods producers that each produce a specific intermediate good $j \in (0,1)$ by means of capital and labor according to the constant return technology described in Equation (3.10). Given the imperfect substitutability between intermediate goods, each good $j \in (0,1)$ is demanded in positive quantity and each firm has local monopoly power. Thus, each intermediate good producer sets the price $P_t(j)$ for its output. However, changing prices entails a convex cost (in terms of the final good)[18] à la Rotemberg (1982), which takes the form

$$\frac{\phi}{2}\left(\frac{P_t(j)}{P_{t-1}(j)} - 1\right)^2 y_t \tag{3.25}$$

where $\phi \in \mathbb{R}_+$ controls for the size of these costs, and is a measure of the degree of price stickiness. In particular, $\phi = 0$ corresponds to the flexible price economy, $\phi = +\infty$ implies the existence of constant prices. Given that the steady state inflation level is zero ($\pi = 1$), it is clear from Equation (3.25) that the cost is nil in the long-run. Firm j set its price so as to maximize its intertemporal profits

$$\max \sum_{t=0}^{\infty} \Phi_{t,t+1}\left(\frac{P_t(j)}{P_t} y_t(j) - \Psi_t(j) y_t(j) - \frac{\phi}{2}\left(\frac{P_t(j)}{P_{t-1}(j)} - 1\right)^2 \overline{y}_t\right) \tag{3.26}$$

[18] This implies that the resource constraint of the economy must be changed to

$$y_t = c_t + i_t + av_t + \frac{\phi}{2}\left(\frac{P_t}{P_{t-1}} - 1\right)^2 \overline{y}_t$$

subject to the demand it faces (Equation (3.23)). $\Phi_{t,t+1}$ is the appropriate discount factor of the firm defined in Section 3.2.3, $\Psi_t(j)$ is the real marginal cost of the firm. In a symmetric equilibrium, The price setting equation gives rise to a standard Phillips curve

$$(1-\varepsilon)y_t + \varepsilon\Psi_t y_t - \pi_t\phi\left(\pi_t - 1\right)y_t + \beta\frac{1+\tau_t^c}{1+\tau_{t+1}^c}\frac{c_t}{c_{t+1}}\phi\pi_{t+1}\left(\pi_{t+1}-1\right)\overline{y}_{t+1} = 0 \quad (3.27)$$

where $\pi_t = P_t/P_{t-1}$. The real marginal cost is given by the gap between the rental rate of capital and the marginal product of capital

$$z_t = \Psi_t\alpha\frac{y_t(j)}{k_t(j)} \quad (3.28)$$

Finally, the monopoly power of each firm affect its vacancy posting policy as

$$\frac{a}{q_t} = \beta\frac{c_t(1+\tau_t^c)}{c_{t+1}(1+\tau_{t+1}^c)}\left(\Psi_{t+1}(1-\alpha)\frac{y_{t+1}(j)}{n_{t+1}(j)} - w_{t+1} + (1-\psi)\frac{a}{q_{t+1}}\right) \quad (3.29)$$

Monetary Authority

The monetary authority conducts monetary policy by adjusting short-term nominal interest rate R_t in response to deviations of inflation π_t from its steady–state value and changes in the output gap. The monetary policy is assumed to be described by the simple Taylor-type interest rate rule

$$R_t = \rho_r R_{t-1} + (1-\rho_r)\left(\overline{R} + \kappa_y\log\left(\frac{y_t}{\overline{y}}\right) + \kappa_\pi\log\left(\frac{\pi_t}{\overline{\pi}}\right)\right) \quad (3.30)$$

where $\rho_r \in [0,1]$, $\kappa_y \in \mathbb{R}_+$ and $\kappa_\pi > 1$.

3.6.2 Results

In this section, we discuss the adjustment dynamics to a fiscal consolidation episode in a nominal economy. However, before preceding to the results, we outline first the relevant parametrization that remains outstanding. In particular, the elasticity of substitution between differentiated goods, ε, is set at 6 implying a steady state markup rate of 20%. The price adjustment cost parameter, ϕ, is set to 58.[19] Given

[19]The choice of $\phi = 58$ is dictated by the fact that it yields the same inflation persistence as a Calvo price setting model with an average duration of price contracts of 3 quarters.

its importance, we will conduct later the sensitivity analysis around its value. In a monetary rule, the parameter governing the reaction of the interest rate to output, κ_y, is set to 0.1, and the response to inflation, κ_π, is set to 1.5. The persistence parameter in the monetary policy rule, ρ_r, is fixed at 0.8.

The Figure 3.16–3.17 compare the transitional paths of fiscal instruments, output and employment for a flexible price (dashed line)–the benchmark experiment described in the previous section– and sticky price (solid line) setups. As already explained, the commencement of fiscal consolidation brings about a negative wealth effect, which plunges the economy in a recession. The concern for output stabilization instructs the central bank to lower the interest rate, which pushes both consumption and investment upward and therefore creates some inflation. But, the concern for inflation makes the central bank increase the interest rate to tame the increase in prices. The inflation starts to raise in the second quarter and reaches a plateau at 0.44%, 3.25 years after fiscal consolidation commencement, and remains at that level for the following 7 quarters, before it starts to fall.

The raising inflation requires *(i)* that government raises higher tax revenue to achieve its debt target, and *(ii)* the central bank to raise nominal interest rates to stabilize prices. The peak in the evolution of labor tax takes place 3.5 years after the fiscal consolidation commences and reaches the value of 29.87% (29.17% in the benchmark case). The long-run tax rate is reduced to 23.5% while in the benchmark case it is 23.8%. Higher labor tax rate and nominal interest rate induce "crowding out" effects on household consumption and investment (as the cost of capital rises). In turn, the employment (and output) losses are larger than in the real benchmark model. The peak in the evolution of output losses occurs at 4.5 years and it amounts to 1.7 percent deviations – 0.22% higher than in the benchmark case. The unemployment reaches its trough earlier at 3.5 years and it is 2.2% (compared to 1.89% in the benchmark case).

These findings are confirmed by results in Table 3.11, which shows that the cumulative employment (and output) losses are larger than under the benchmark case. The discounted output losses are 21.05% – 3.68% higher than in the benchmark case. Likewise, the employment losses are higher across all of the horizons. For

Figure 3.16: Fiscal Consolidation: Sticky Prices (I)

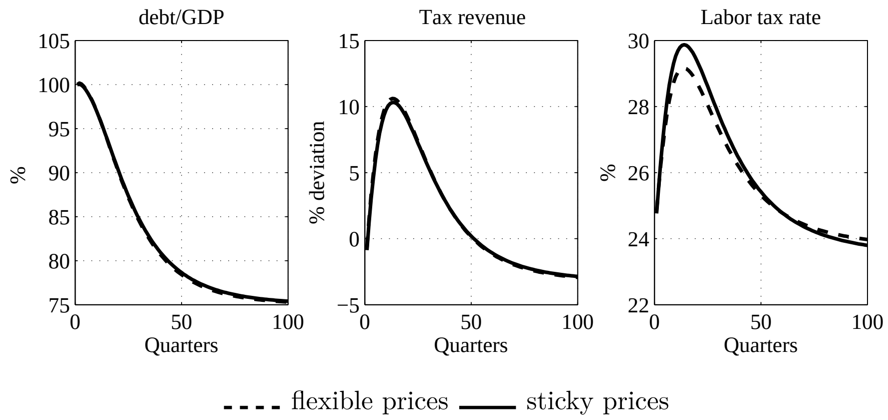
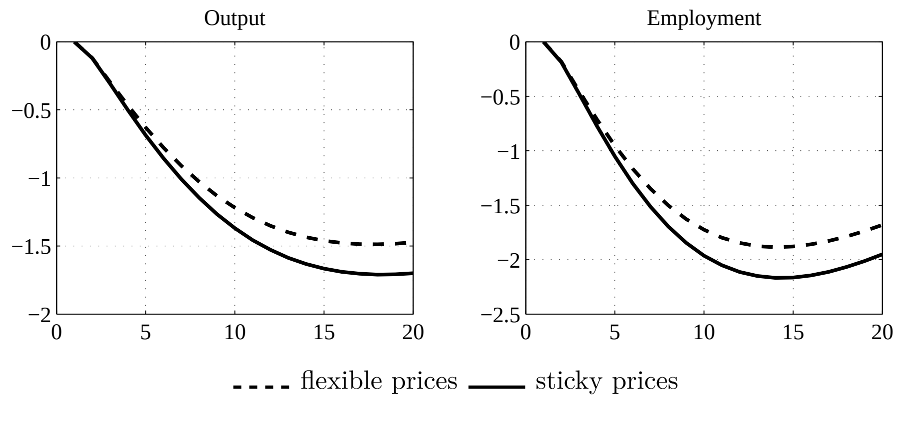


Figure 3.17: Evolution of Output and Employment (II)



example, at 5 years 31.75% – 3.89% higher than in the benchmark case. The results

Table 3.11: Cumulative losses: Sticky Prices

Horizon	1 Quarter	1 Year	2 Years	5 Years	20 Years	50 Years	Discounted
Output	0.12	0.93	4.63	23.65	66.26	16.86	21.05
Employment	0.19	1.44	7.01	31.75	51.32	-9.07	–

indicate that the price stickiness does play a role in the fiscal adjustment process, which comes at higher output and employment losses. The interplay between fiscal and monetary policy is relevant for the policy consideration as there is a direct trade-off between the fiscal consolidation and price stabilization.

3.6.3 Sensitivity analysis

The preceding results have shown that the interplay between fiscal and monetary policy can hinder fiscal consolidation, and that the output and employment costs of reducing public debt can be sizable in the short to medium run. This section assesses the robustness of the previous findings to alternative settings for the consolidation policy. In particular, the sensitivity to an alternative choice of fiscal instruments (namely, consumption tax), the degree of price rigidity, and the different degree of monetary authority responsiveness to output and price stabilization are investigated.

Consumption tax

The preceding section investigated the implications for employment and output of a reduction in nominal debt accommodated by adjusting labor tax rate. In this section, fiscal consolidation is obtaned through adjustments in the consumption tax instead. Figures 3.18 and 3.19 report the transitional path of employment, output and fiscal instruments obtained in this case. As the predominant interest of this section is to explore the nominal aspect of fiscal consolidation, we compare an economy with sticky prices (plain line) to an economy with flexible prices (dashed line) when, in both cases, the fiscal adjustment is performed by changes in the consumption tax rate. The right panel of Figure 3.18 shows, to achieve the same debt transition path, government needs to follow the identical tax revenue path by adjusting its consumption tax. The peak in the evolution of consumption tax rate, in the nominal economy, occurs at 3.5 years after the fiscal consolidation begins –same as in the real economy– and it amounts to 9.98% –a marginally smaller adjustment than for a real economy, 10.3%.

Figure 3.18: Fiscal Consolidation: Sticky Prices (I)

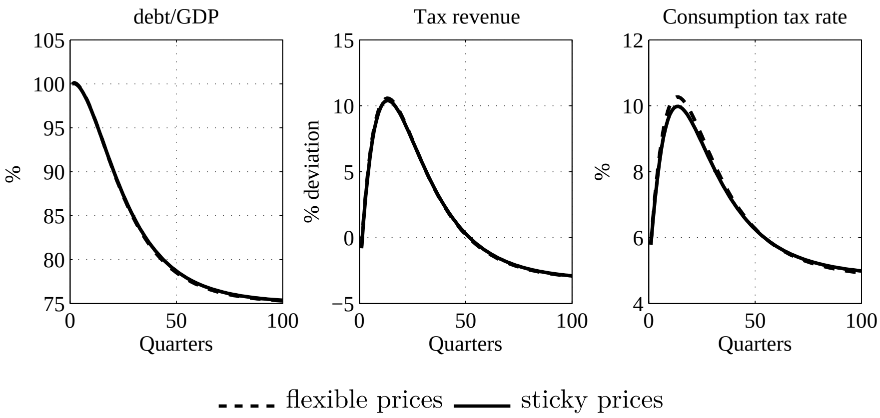


Figure 3.18 indicates that employment (and output) losses are smaller in the nominal economy. The employment losses reach its peak after 3.5 years and are 1.1% – compared to 1.28% in the real economy. The output reaches its trough after 4.5 years and amount to 0.91% – this is smaller than for a case of flexible prices, which is 1.01%.

These findings are further confirmed by the results shown in Table 3.12 where adjusting the consumption tax produces than it was the case in real economy. For example, the employment cumulative losses in two years are 4.16% – while we previously had it 4.45%, in the real economy.

These results suggest that, when the consumption tax is an instrument of choice, the nominal dimension of fiscal austerity cannot be ignored, but it is, nevertheless,

Figure 3.19: Evolution of Output and Employment (II)

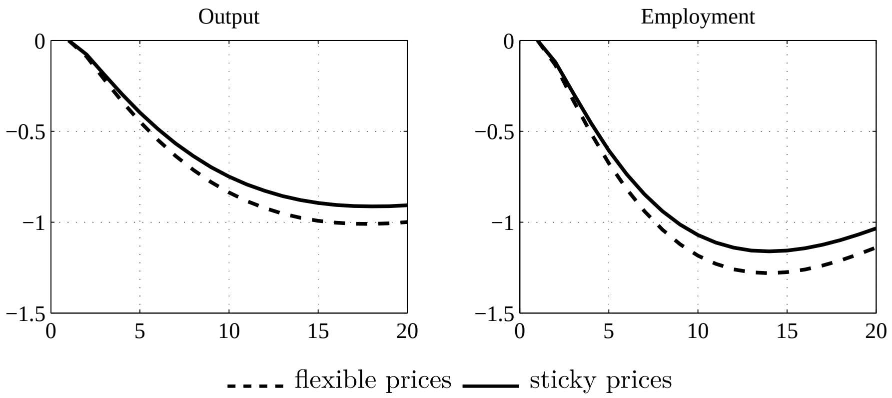


Table 3.12: Cumulative losses: Consumption Tax Adjustment Under Sticky Prices

Horizon	1 Quarter	1 Year	2 Years	5 Years	20 Years	50 Years	Discounted
Output	0.08	0.60	2.77	13.29	35.32	5.67	9.50
Employment	0.13	0.92	4.16	17.75	26.56	-8.96	–

less prominent than for the labor tax. Thus, it is possible for a government to minimize the hindering effects of monetary policy on its fiscal consolidation effort by adjusting consumption tax.

The degree of price rigidity

In this section we investigate how the degree of nominal rigidities affects the fiscal consolidation. Figure 3.20 – 3.21 show the transitional paths of fiscal instruments, output and employment as the degree of price rigidity, ϕ, varies in the range from 0 to 200 –the benchmark experiment is set at $\phi = 58$.[20] From the right panel of Figure 3.20 we see that the major difference in the labor tax, across different degrees of price rigidity, is in the first quarter. The larger the degree of nominal sluggishness the larger the initial increase in the tax, as the inflation tax cannot be used to generate more tax revenues. Once inflation adjusts further, the effect of price rigidity on the response of labor tax vanishes. On one hand, for a very low price rigidity, $\phi = 0$, the initial response of labor tax is a fall from its steady state level – from 25% to 24.6% – before it starts to increase. On the other hand, for a very high degrees of price rigidities, $\phi = 200$, the labor tax sharply increases from its steady state level – from 25% to 29.2% – but from the second quarter the labor tax adjustment is about the same as for other cases. The peak responses in the evolution of labor tax occurs after 3.5 years following the fiscal austerity and it is only slightly higher for flexible prices – 29.9% as opposed to 29.4% for highly sticky prices.

Figure 3.21 illustrates that, for flexible prices, $\phi = 0$, the employment (and output) losses are smaller in the first few quarters but consequently are more profound than for the sticky prices. The results indicate that the employment and output are both falling in the degree of price rigidity, but those deviations are smaller for a higher degrees of price rigidities.

As we have previously seen for a real economy, when prices are able to fully adjust, the intertemporal substitution effect will push inflation up straight away

[20] Note that the case $\phi = 0$ does not exactly correspond to our benchmark economy as the benchmark economy did not feature imperfect competition.

Figure 3.20: Fiscal Consolidation: Sticky Prices (I)

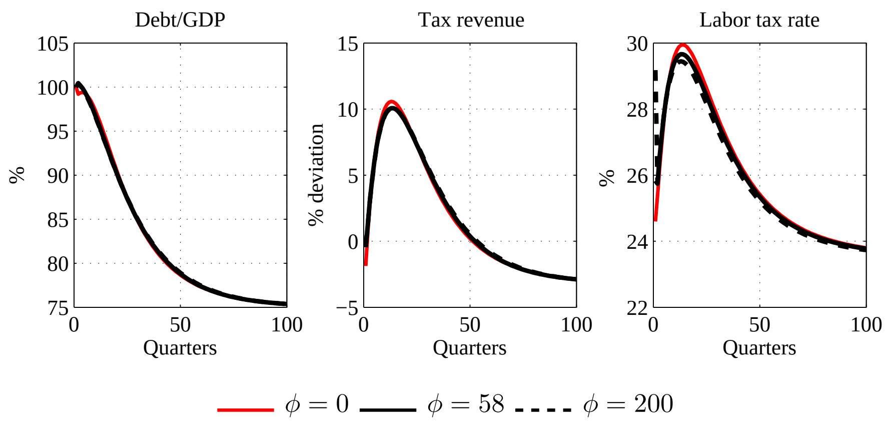
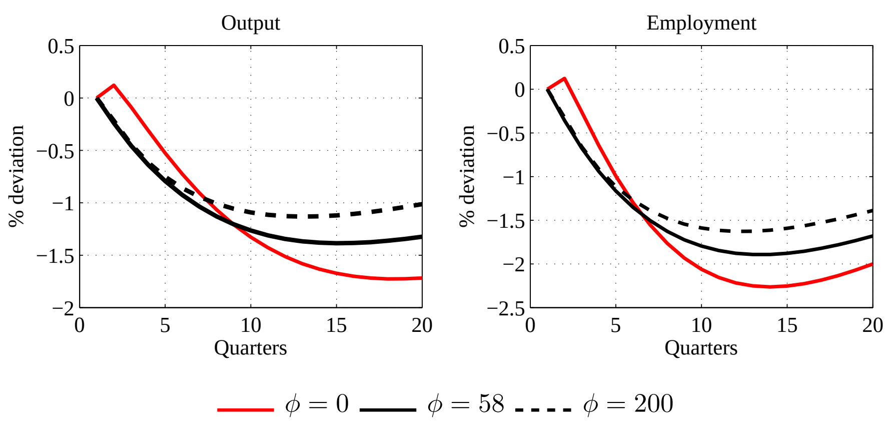


Figure 3.21: Evolution of Output and Employment: Sticky Prices (II)



in the first quarter following the fiscal consolidation. The central bank then reacts to stabilize prices by increasing the nominal interest rate. The consumption drops sharply in the first quarter and investment at first increases in the attempt by households to smooth their future consumption. This produces profound employment and output losses. Contrary, when prices are slow to adjust the response of the households will be muted, thus, producing smaller employment and output losses.

Table 3.13: Cumulative losses: Varying Price Stickiness

Horizon	1 Quarter	1 Year	2 Years	5 Years	20 Years	50 Years	Discounted
Output							
$\phi = 0$	-0.12	0.27	3.50	22.45	65.21	15.78	20.00
$\phi = 58$	0.24	1.33	5.22	21.27	50.79	0.31	8.64
$\phi = 200$	0.22	1.27	4.84	17.93	32.99	-20.01	-6.10
Employment							
$\phi = 0$	-0.12	0.78	6.39	32.14	51.98	-8.38	–
$\phi = 58$	0.36	1.97	7.62	29.40	45.92	-15.14	–
$\phi = 200$	0.32	1.89	7.15	25.76	35.91	-26.07	–

These results are confirmed by the cumulative employment and output losses presented in Table 3.13. For example, the discounted cumulative output losses are highest for flexible prices and in fact turn into cumulative gains for very high degree of price rigidities – 20% employment losses for $\phi = 0$ versus 6.1% employment gains for $\phi = 200$. After 5 years following the beginning of debt reduction, there is negative relationship between the employment losses and the degree of price rigidity. For example, for fully flexible prices the employment loss is about 32% but this is reduced down to about 26% for high degree of price rigidity, $\phi = 200$.

These results indicate that when prices are flexible the monetary policy is non neutral and the central bank in its effort to stabilize prices can significantly hinder the fiscal consolidation efforts.

The conduct of monetary policy

This section explores if the central bank, through its concern for inflation and output fluctuations, affects the process of fiscal consolidation. Figure 3.22 shows the evolution of output and employment as we vary the degree of reactiveness by central bank to inflation, κ_π, and output fluctuations, κ_y.

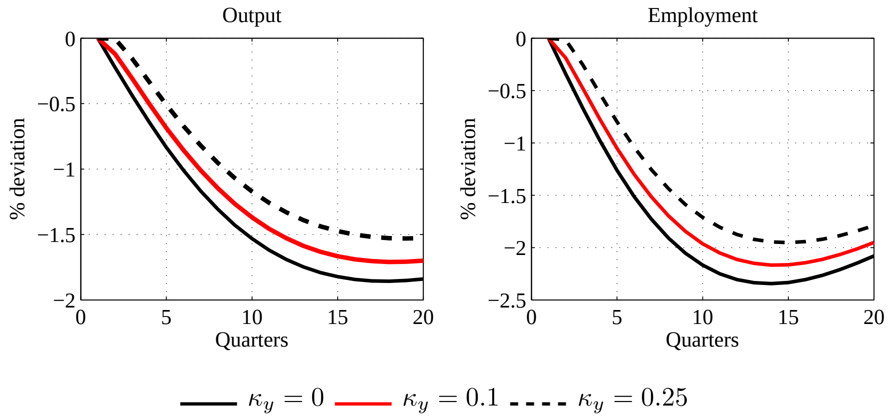
The degree of responsiveness to output fluctuations, κ_y, varies in the range from 0 to 0.25 –the benchmark experiment is set at $\kappa_y = 0.1$. Naturally, greater emphasis on output stabilization is expected to bring about smaller losses in output and employment. This is confirmed by results shown in Panel (a) of Figure 3.22 where an increase in the reaction of monetary authority to the output fluctuations leads to smaller output and employment losses. Under this policy, the inflation increases and subsequently prompts the central bank to increase nominal interest rate. Higher nominal interest rate makes the public debt more expensive and instigates the households to decrease its debt holdings. Subsequently, this effect aids the whole debt reduction. Consequently, the fiscal revenue required to retire the public debt will not be as high as previously and, thus, the labor tax rate adjustment is lower. For example, with $\kappa_y = 0$ the peak in the evolution of tax rate is 30.25% while with $\kappa_y = 0.25$ it is 29.4% (after 3.5 years following the commencement of fiscal consolidation).

To explore the effect of price stabilization on the fiscal consolidation, the degree of responsiveness to output fluctuations, κ_π, is varied in the range from 1.01 to 2.5 –the benchmark experiment is set at $\kappa_\pi = 1.5$– and to facilitate the exposition a policy rule with $\kappa_y = 0$ is used. Naturally, reaction by central bank to subdue inflation by increasing nominal interest rates will suppress the output and employment further. This is affirmed by Panel (b) of Figure 3.22 which depicts the evolution of employment and output as a function of the reaction to inflation, κ_π. An increased emphasis on price stability leads to higher output and employment losses. This points to the existence of another trade-off between price stabilization and fiscal consolidation effort.

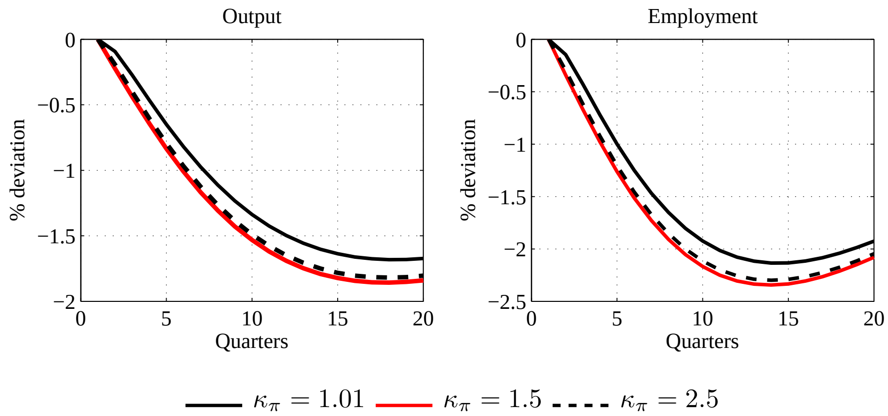
The cumulative output losses as presented in Table 3.14 similarly point out that greater emphasis on the output stabilization leads to lower output and employment

Figure 3.22: Evolution of Output and Employment: Varying κ_π and κ_y

(a) Reaction to Output Gap (κ_y)



(b) Reaction to Inflation (κ_π)



losses in the short– and medium–run. For example, for the higher reactiveness by central bank to output fluctuations, $\kappa_y = 0.25$, after 1 years following the beginning of fiscal consolidation we have 0.5% loss in output –0.93% in the benchmark experiment – and 0.8% in employment – 1.44% in the benchmark experiment.

Table 3.14: Cumulative losses: Varying Response to Output

Horizon	1 Quarter	1 Year	2 Years	5 Years	20 Years	50 Years	Discounted
Output							
$\kappa_y = 0$	0.22	1.30	5.62	26.50	72.31	22.91	26.15
$\kappa_y = 0.1$	0.12	0.93	4.63	23.65	66.26	16.86	21.05
$\kappa_y = 0.25$	0.01	0.50	3.45	20.19	58.91	9.60	14.90
Employment							
$\kappa_y = 0$	0.34	1.99	8.40	35.21	55.98	-4.70	–
$\kappa_y = 0.1$	0.19	1.44	7.01	31.75	51.32	-9.07	–
$\kappa_y = 0.25$	0.02	0.80	5.33	27.52	45.58	-14.35	–

Table 3.15: Cumulative losses: Varying Response to Inflation

Horizon	1 Quarter	1 Year	2 Years	5 Years	20 Years	50 Years	Discounted
Output							
$\kappa_\pi = 1.01$	0.09	0.83	4.39	23.05	64.74	15.22	19.76
$\kappa_\pi = 1.5$	0.22	1.30	5.62	26.50	72.31	22.91	26.15
$\kappa_\pi = 2.5$	0.19	1.20	5.35	25.75	70.50	20.83	24.55
Employment							
$\kappa_\pi = 1.01$	0.15	1.30	6.67	31.02	50.01	-10.35	–
$\kappa_\pi = 1.5$	0.34	1.99	8.40	35.21	55.98	-4.70	–
$\kappa_\pi = 2.5$	0.30	1.83	8.02	34.29	54.44	-6.36	–

The results indicate that the interplay between fiscal and monetary policies is non neutral. One one hand, the central bank's effort to stabilize the output fluctuations can ease the recession brought by fiscal consolidation but it prolongs the whole process of the debt reduction. On the other hand, the price stabilization efforts hinder the public debt reduction process and, thus, leads to greater output and employment losses.

3.7 Conclusion

This paper offers a quantitative evaluation of employment (and output) losses generated during the fiscal consolidation episodes. It does this in the context of a textbook neoclassical growth model featuring —search and matching á la Mortensen and Pissarides (1994) and Shimer and Rogerson (2010)— frictions on the labor market. Sovereign debt reduction is achieved by imposing fiscal authority, either by tax hikes or government expenditures cuts, which plunges the economy in a persistent recession and therefore generates output and employment losses. In the baseline experiment —a targeted 25% debt reduction— unemployment increases by about 50%, starting from 5.5% and reaching 7.3% after 3.35 years. These employment losses are persistent and last on average 12 years. Furthermore, at the trough of the recession (4.5 years following the beginning of the adjustment), output is 1.5% below its initial steady state.

These losses are found to be especially acute during times of recession as there are competing goals placed on the labor tax adjustment by *(i)* fiscal consolidation and *(ii)* output stabilization. The sensitivity analysis indicates further that sizable and speedier debt adjustments are associated with bigger employment and output losses. The front–loading of debt reduction brings bigger initial adjustment which magnifies the employment loss in the short–run. However, economy recovers quicker compared to gradualist approach. A slower adjustment allows for smooth debt adjustment that limits the initial employment loss, but in that case it lasts longer and the economy, thus, suffers longer. Likewise, the more determined fiscal authority is to front–load its debt, the bigger are employment and output losses, but the painful adjustment period is shorter. These findings point to the existence of an intertemporal trade–off between short–run losses from fiscal consolidation and long–run gains from reduced debt.

Moreover, the paper shows that, as already found in the econometric literature (see e.g. Alesina, Favero, and Giavazzi (2014)), the exact details of the consolidation plan do matter; government spending cut versus tax hikes, the type of tax instrument used to achieve fiscal adjustment, and the timing of the plan. Finally, monetary policy interplays with fiscal policy. The central bank, by adjusting the nominal interest rate, affects the value of debt used by households to transfer wealth from one period to the next. Higher nominal interest rate increases the value of debt, which then reduces its demand by households. This aids the whole debt reduction process and, thus, speeding up the fiscal consolidation in the short–run.

The results of this paper suggest that debt reduction should be accompanied with reforms on the labor market to tame down labor market frictions. This is left for future research.

—APPENDIX—

3.A Model

3.A.1 Household

The household has preferences over consumption and leisure described by the following intertemporal utility function

$$\sum_{t=0}^{\infty} \beta^t \left(\log c_t - \vartheta \frac{n_t^{1+\nu}}{1+\nu} \right) \tag{3.A.1}$$

subject to the budget constraint, the law motion of capital and the law motion of employment, respectively,

$$(1+\tau_t^c)c_t + i_t + b_t = r_{t-1}b_{t-1} + (1-\tau_t^w)w_t n_t + (1-\tau_t^k)z_t k_t + \Pi_t + T_t \tag{3.A.2}$$

$$k_{t+1} = \left(1 - \frac{\varphi}{2} \left(\frac{i_t}{i_{t-1}} - 1 \right)^2 \right) i_t + (1-\delta) k_t \tag{3.A.3}$$

The optimality conditions are given as

$$\lambda_t = \frac{1}{c_t(1+\tau_t^c)} \tag{3.A.4}$$

$$\lambda_t = \beta \lambda_{t+1} r_t \tag{3.A.5}$$

$$\zeta_t = \beta \left(\lambda_{t+1}(1-\tau_{t+1}^k) z_{t+1} + \zeta_{t+1}(1-\delta) \right) \tag{3.A.6}$$

$$\begin{aligned} \lambda_t = & \zeta_t \left(1 - \frac{\varphi}{2} \left(\frac{i_t}{i_{t-1}} - 1 \right)^2 - \varphi \left(\frac{i_t}{i_{t-1}} - 1 \right) \frac{i_t}{i_{t-1}} \right) \\ & + \beta \zeta_{t+1} \varphi \left(\frac{i_{t+1}}{i_t} - 1 \right) \left(\frac{i_{t+1}}{i_t} \right)^2 \end{aligned} \tag{3.A.7}$$

where λ_t and ζ_t are the Lagrange multipliers associated, respectively, to the budget constraint and the capital equation. This system rewrites as The household's optimal behavior is then characterized by the set of Euler conditions

$$\frac{1}{c_t(1+\tau_t^c)} = \beta \frac{r_t}{c_{t+1}(1+\tau_{t+1}^c)} \tag{3.A.8}$$

$$q_t^i = \beta \frac{c_t(1+\tau_t^c)}{c_{t+1}(1+\tau_{t+1}^c)}(z_{t+1}(1-\tau_{t+1}^k) + q_{t+1}^i(1-\delta)) \tag{3.A.9}$$

where $q_t^i = \zeta_t/\lambda_t$ denotes the marginal Tobin's Q.

3.A.2 Firm

The firm decides its production and vacancy posting plans by maximizing its intertemporal discounted profit subject to the law of motion of employment

$$\max \sum_{t=0}^{\infty} \Psi_{t,0} \left(A_t k_t^{\alpha}(j) n_t(j)^{1-\alpha} - z_t k_t(j) - w_t n_t(j) - a v_t(j) \right) \tag{3.A.10}$$

subject to

$$n_{t+1}(j) = q_t v_t(j) + (1-\psi) n_t \tag{3.A.11}$$

$\Psi_{t,0}$ denotes the discount factor of the firm between periods 0 and t, given that, in the model, the interests of the manager of the firm are aligned with those of the shareholder –the household– the proper discount factor is given by $\Psi_{t,0} \propto \beta^t(1+\tau_0^c)\frac{\partial U(c_t,n_t)}{\partial c_t}/(1+\tau_t^c)\frac{\partial U(c_0,n_0)}{\partial c_0}$. The optimality conditions are then given as

$$\mu_t(j) = \Psi_{t+1,t} \left\{ (1-\alpha)\frac{y_{t+1}(j)}{n_{t+1}(j)} - w_{t+1} + (1-\psi)\mu_{t+1}(j) \right\} \tag{3.A.12}$$

$$a = q_t \mu_t(j) \tag{3.A.13}$$

$$z_t = \alpha \frac{y_t(j)}{k_t(j)} \tag{3.A.14}$$

where $\mu_t(j)$ denotes the Lagrange multiplier associated to the law of motion of employment.

The optimal production and vacancy posting plans are characterized by the following optimality conditions

$$z_t = \alpha \frac{y_t(j)}{k_t(j)} \tag{3.A.15}$$

$$\frac{a}{q_t} = \beta \frac{c_t(1+\tau_t^c)}{c_{t+1}(1+\tau_{t+1}^c)} \left((1-\alpha) \frac{y_{t+1}(j)}{n_{t+1}(j)} - w_{t+1} + (1-\psi) \frac{a}{q_{t+1}} \right) \tag{3.A.16}$$

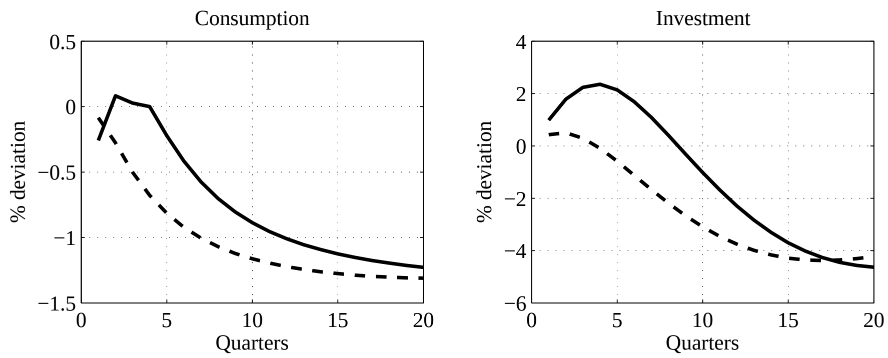
The first condition is the standard demand for capital. The second condition determines the optimal vacancy posting behavior–and hence the optimal employment level.

3.B Additional Figures

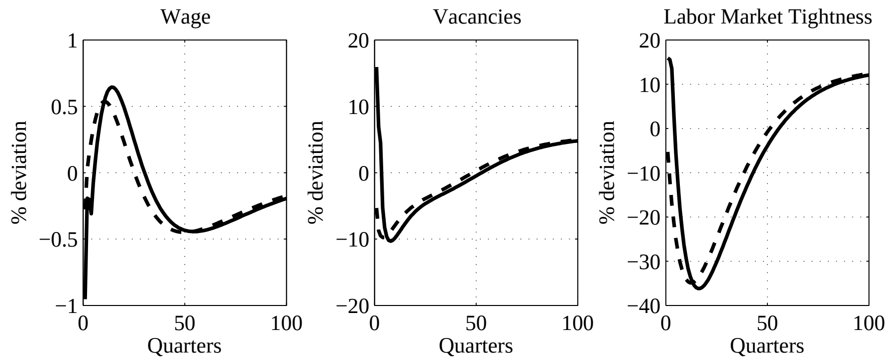
3.B.1 Real Model

Figure 3.23: Macroeconomic responses (Anticipated Debt Reduction Experiment)

(a) Good Market



(b) Labor Market

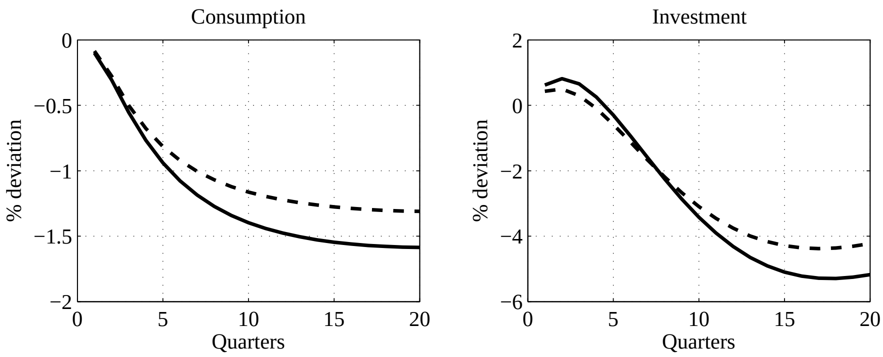


- - - - Immediate debt adjustment
—— Expected future debt adjustment

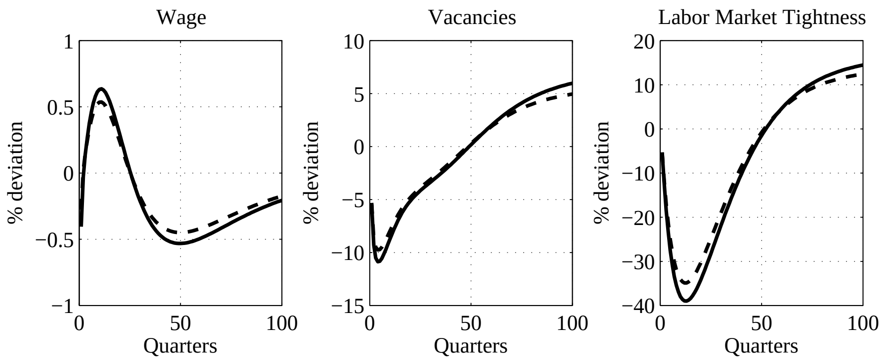
3.B.2 Sticky Price Model

Figure 3.24: Macroeconomic responses (Sticky Prices Experiment)

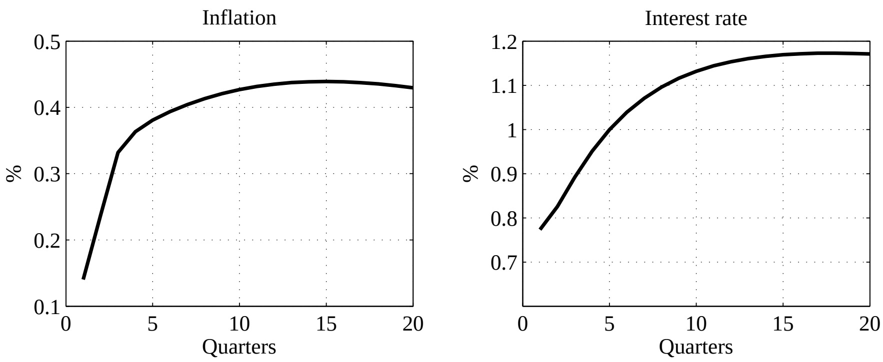
(a) Good Market



(b) Labor Market



(c) Monetary block



flexible prices sticky prices

Figure 3.25: Macroeconomic responses: Adjusting Consumption Tax Rate

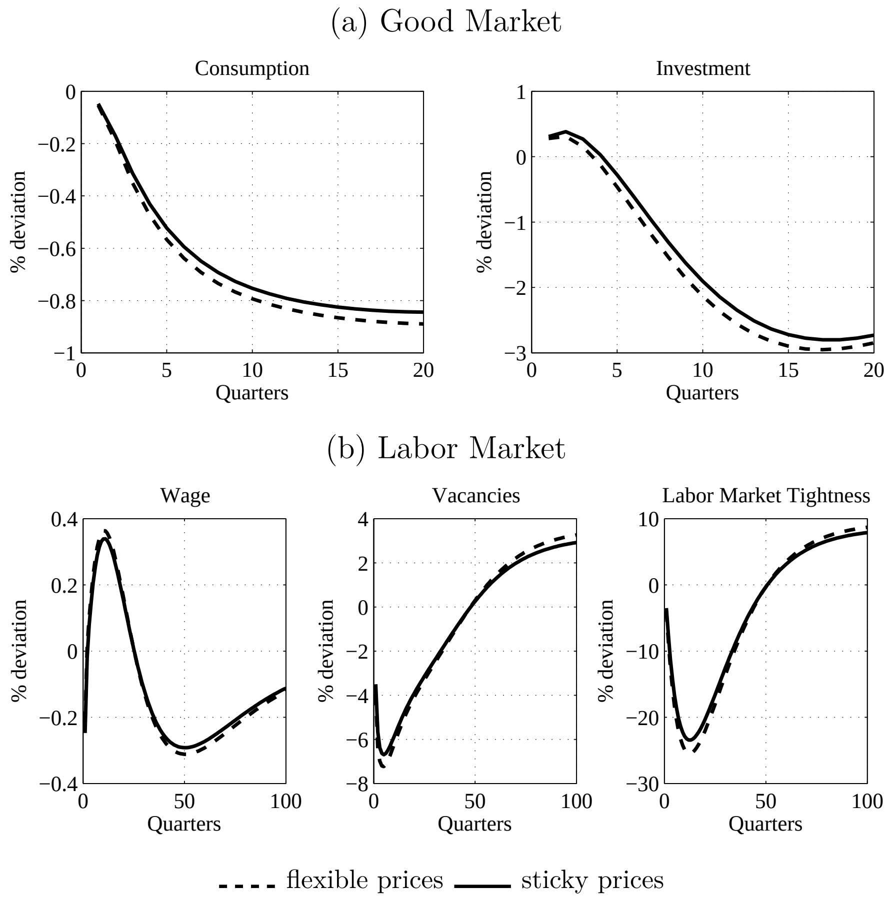


Figure 3.26: Macroeconomic responses: Varying the degree of price rigidity

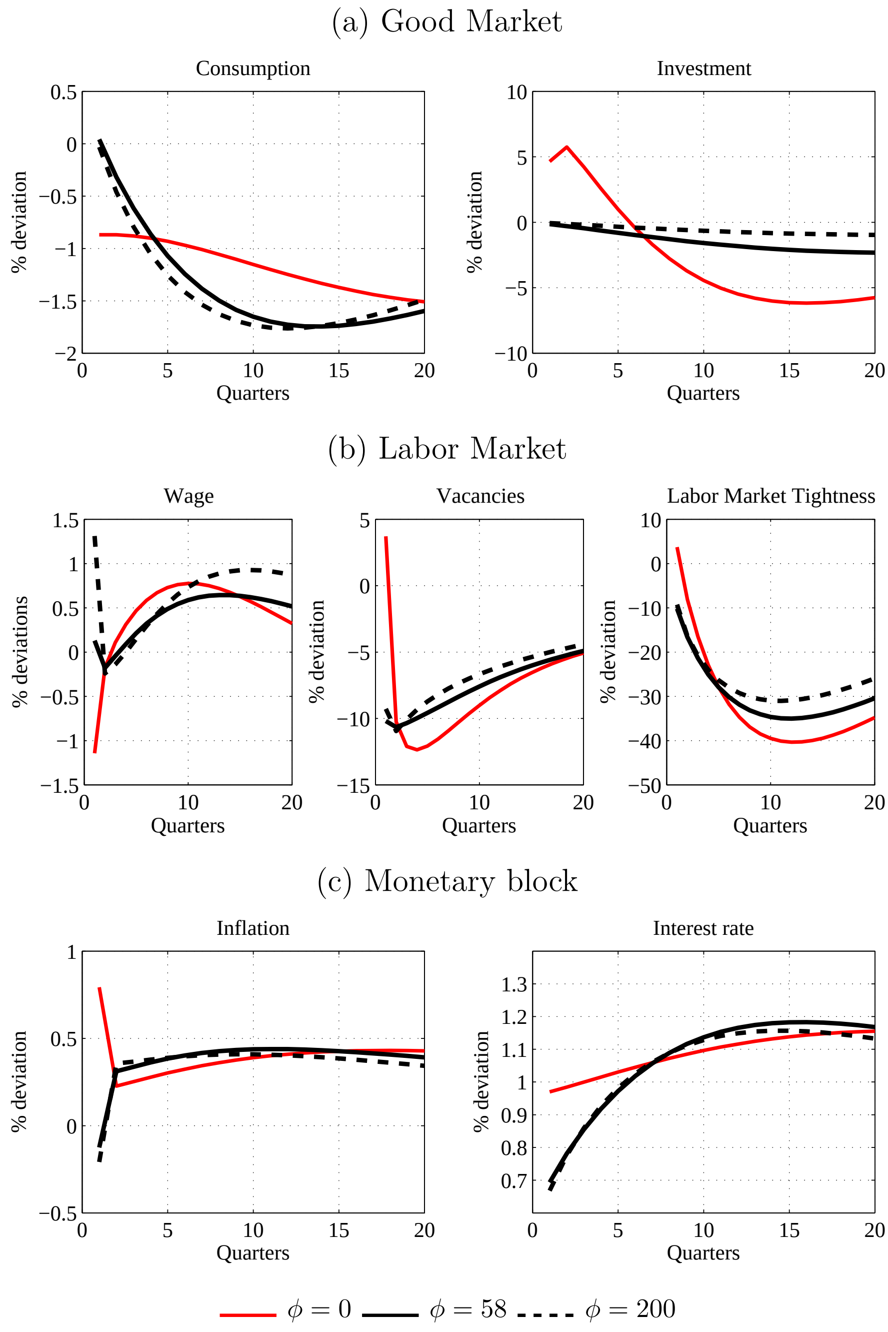


Figure 3.27: Fiscal Consolidation: Reaction to Output Gap

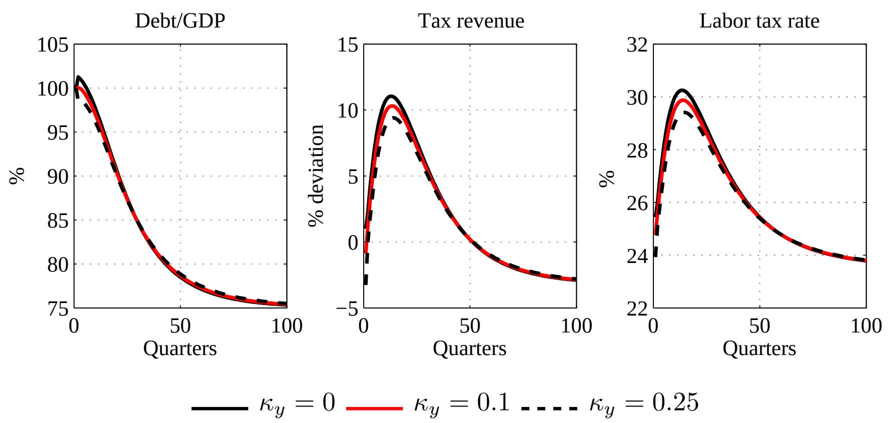
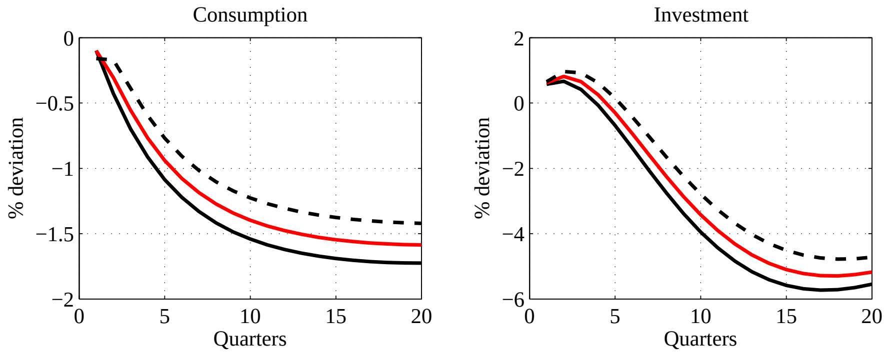
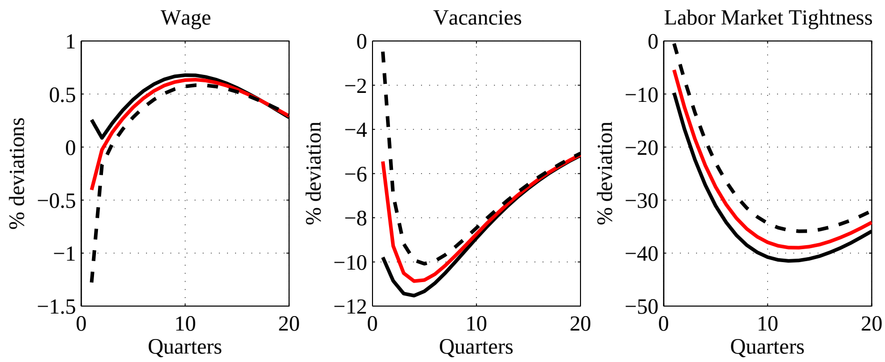


Figure 3.28: Macroeconomic responses: Reaction to Output Gap

(a) Good Market



(b) Labor Market



(c) Monetary block

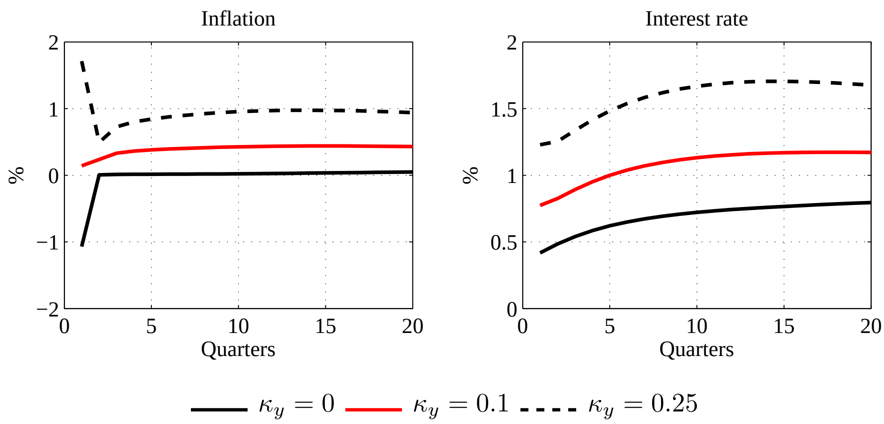


Figure 3.29: Fiscal Consolidation: Reaction to Inflation

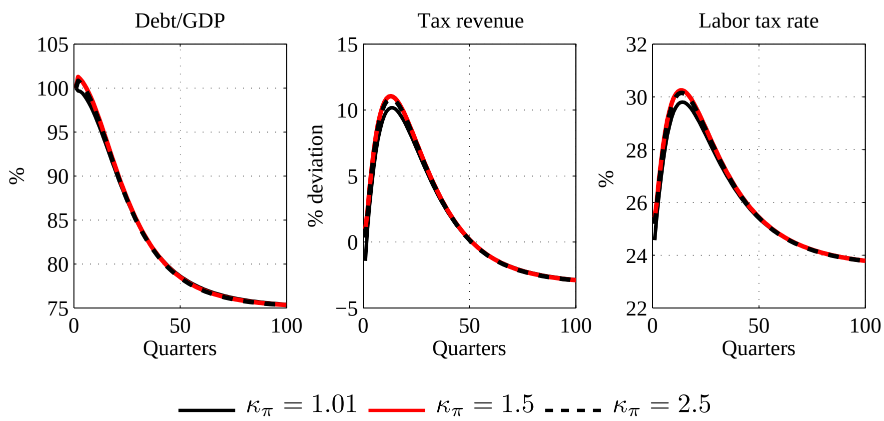
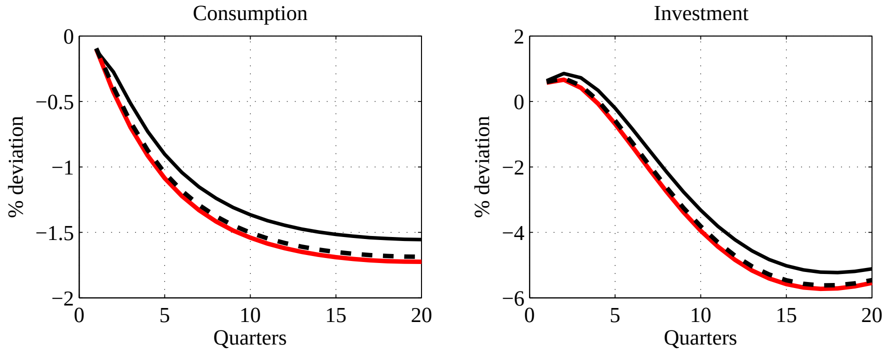
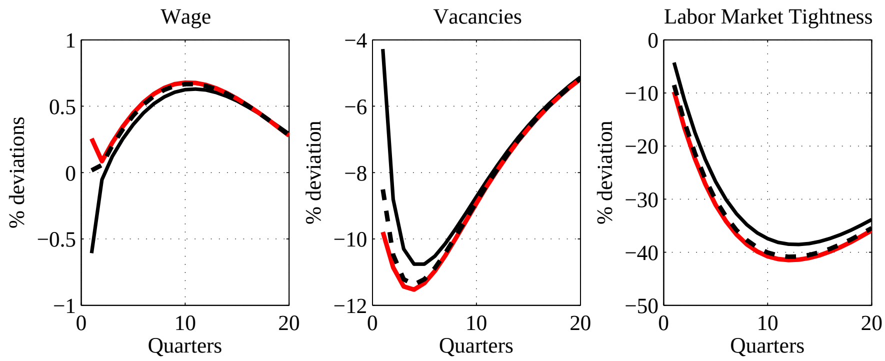


Figure 3.30: Macroeconomic responses: Reaction to Inflation

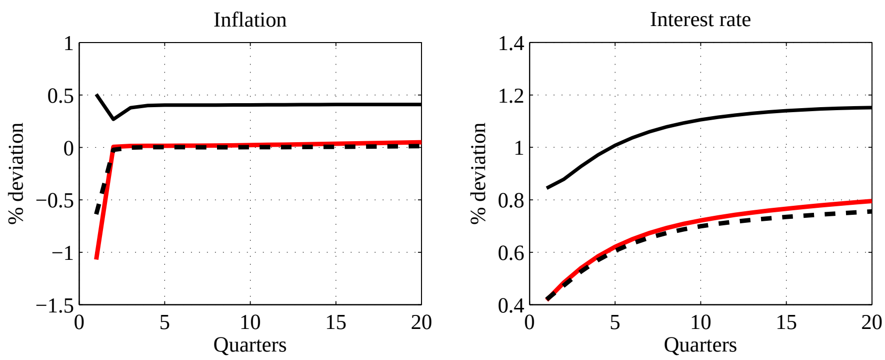
(a) Good Market



(b) Labor Market



(c) Monetary block



$\kappa_\pi = 1.01$ $\kappa_\pi = 1.5$ $\kappa_\pi = 2.5$

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Bern, February 22, 2017

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